THE SOUTH AFRICAN JOURNAL OF SCIENCE

VOLUME XLI

BEING THE

REPORT

OF THE

FORTY-SECOND ANNUAL MEETING

OF THE

SOUTH AFRICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

JOHANNESBURG

1944

3rd, 4th and 5th JULY

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SUID-AFRIKAANSE JOURNAL VAN WETENSKAP

DEEL XLI

SYNDE DIE

VERSLAG

VAN DIE

TWEE-EN-VEERTIGSTE JAARVERGADERING

VAN DIE

SUID-AFRIKAANSE GENOOTSKAP

VIR DIE

BEVORDERING VAN WETENSKAP

JOHANNESBURG

1944

3, 4 en 5 JULIE

JOHANNESBURG
UITGEGEE DEUR DIE GENOOTSKAP
en
Gedruk deur RADFORD, ADLINGTON, BPK , Rissik-en Marshallstraat,
Johannesburg, Suid-Afrika

1945

CONTENTS.

THE

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(1944, JOHANNESBURG)

Vol. XLI FEBRUARY, 1945 Vol. XLI

EDITORIAL NOTE.

The present volume of the JOURNAL being the report of the forty-second Annual Meeting of the Association and the fifth during the war period, shows a gratifying return to normal pre-war standards, both in the number and extent of the contributions.

As in 1942, a symposium was organised by Professor John Phillips, Mr. Jas Gray and Dr. J. B. Robertson, the subject in 1944 being "A Scientific Approach to the Problems of Post-war Employment," and the addresses on various aspects of this subject are included in this volume, either in full or in abstract.

I have to offer my grateful thanks to Dr. R. A. Dyer for his generous assistance in the editing of the papers in Section C for several years, and to many authors for their kind co-operation in any necessary abridgment of their papers.

Hon Associate Editor.

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PROCEEDINGS OF THE FORTY-SECOND ANNUAL GENERAL MEETING OF MEMBERS HELD AT KELVIN HOUSE, JOHANNESBURG, ON TUESDAY, 4th JULY, 1944, AT 12 NOON.

VERRIGTINGS VAN DIE TWEE-EN-VEERSTIGSTE ALGEMENE JAARVERGADERING VAN LEDE IN KELVIN-HUIS JOHANNESBURG, OM TWAALF UUR OP DINSDAG 4 JULIE GEHOU.

Present/Teenwoordig.—Colonel/Kol. J. G. Rose (President, in the chair), Dr. H. L. Alden, Miss/Mej. J. A. Andrews, Mr./Mnr. S. B. Asher, Dr. A. E. H. Bleksley, Mr./Mnr. E. C. Chubb, Mr./Mnr. R. Craib, Miss/Mej. C. G. Crocker, Dr. G. de Kock, Dr. R. A. Dyer, Dr. V. F. Fitzsimons, Mr./Mnr. F. E. Gordon-Helps, Dr. T. D. Hall, Mr./Mnr. J. Harcus, Dr. Marguerita Henrici, Dr. J. D. J. Hofmeyr, Captain/Kapt. H. A. G. Jeffreys, Dr. R. J. A. Jordan, Mr./Mnr. J. D. Krige, Dr. Hilda Kuper, Mr./Mnr. D. R. Macfarlane, Professor L. F. Maingard, Mr./Mnr. B. D. Malan, Mr./Mnr. D. B. D. Meredith, Dr. Margaretha G. Mes. Mr./Mnr. A. O. D. Mogg, Professor S. M. Naude, Professor John Orr, Dr. E. Percy Phillips, Dr. A. Pijper, Dr. J. I. Quin, Dr. Austin Roberts, Dr. J. B. Robertson, Professor G. H. Stanley, Miss/Mej. E. L. Strang, Professor C. van Riet Lowe, Dr. H. Weinmann, Dr. L. H. Wells, Miss/Mej. E. E. Wijers, Dr. H. E. Wood, Professor H. H. Paine (Honorary General Secretary/Ere-algemene Sekretaris), and Mr./Mnr. A. J. Adams (Assistant General Secretary/Assistent-algemene Sekretaris).

1. Minutes.—The Minutes of the Forty-first Annual General Meeting, held at Johannesburg on the 29th June, 1943, and printed on pages iii to vii of the Report of the Johannesburg Session (Volume XL of the Journal) were confirmed.

Notule.—Die Notule van die Een-en-veerstigste Algemene Jaarvergadering, gehou in Johannesburg op 29 Junie 1943 en gedruk op bladsye iii tot vii van die Verslag van die Johannesburgse Byeenkoms (Deel XL van die Journal) is goedgekeur.

2. Greetings and Apologies.—The Honorary General Secretary reported that messages for a successful meeting had been received from Dr. H. H. Dodds, Professor A. P. G. Goossens, Mr. J. D. Rheinallt Jones, Mr. F. R. Paver and Mr. J. H. Power.

Groete en Verontskuldigings.—Die Ere-algemene Sekretaris het gerapporteer dat beste wense vir 'n suksesvolle vergadering ontvang is van Dr. H. H. Dodds, Professor A. P. J. Goossens, Mnr. J. D Rheinallt Jones, Mnr. F. R. Paver en Mnr. J. H. Power.

It was noted that apologies for absence had been received from/ontvange verontskuldigings vir afwesigheid is genoteer van Mr./Mnr. James Gray, Mrs./Mev. L. Jeffreys, Mr./Mnr. J. D. Rheinallt Jones, Professor P. R. Kirby, Dr. F. E. T. Krause, Mr./Mnr. A. J. Limebeer, Mr./Mnr. F. R. Paver and/en Mr./Mnr. J. H. Power.

Mr. E. C. Chubb stated that he had been requested by Mr. E. B. Dunkerton and Mr. J. F. Schofield to apologise for their absence and to extend their greetings to the meeting.

Mnr. E. C. Chubb het meegedeel dat Mnr. E. B. Dunkerton en Mnr. J. F. Schofield hom versoek het om hulle verontskuldigings vir afwesigheid en hulle groete aan die vergadering oor te bring.

3. Annual Report of Council for the Year Ended 30th June, 1944.—The Annual Report of the Council for the year ended 30th June, 1944, having been duly suspended on the Notice Board, was taken as read and adopted.

JAARVERSLAG VAN DIE RAAD VIR DIE JAAR TOT OP 30 JUNIE 1944.—Die Jaarverslag van die Raad vir die Jaar tot op 30 Junie 1944, wat behoorlik op die Kennisgewingsbord gepubliseer was, is as gelees beskou en goedgekeur.

4. ANNUAL REPORT OF THE HONORARY GENERAL TREASURER AND STATEMENT OF ACCOUNTS FOR THE YEAR ENDED 31ST MAY, 1944.—The Honorary General Treasurer's Report and the Statement of Accounts for the year ended 31st May, 1944, having been duly displayed on the Notice Board, were taken as read and adopted.

JAARVERSLAG VAN DIE ERE-ALGEMENE PENNINGMEESTER EN STAAT VAN REKENINGE VAN DIE JAAR TOT OP 31 MEI 1944.—Die verslag van die Ere-algemene Penningmeester en die Staat van Rekeninge vir die jaar tot op 31 Mei 1944, wat behoorlik op die Kennisgewingsbord gepubliseer is, is as gelees beskou en goedgekeur.

5. ANNUAL REPORT OF THE HONORARY LIBRARIAN FOR THE YEAR ENDED 30TH JUNE, 1944.—The Annual Report of the Honorary Librarian for the year ended 30th June, 1944, having been duly suspended on the Notice Board, was taken as read and adopted.

JAARVERSLAG VAN DIE ERE-BIBLIOTEKARIS VIR DIE JAAR TOT OP 30 JUNIE 1944, wat behoorlik op die Kennisgewingsbord gepubliseer is, is as gelees beskou en goedgekeur.

6. ELECTION OF GENERAL OFFICERS AND MEMBERS OF COUNCIL FOR 1944-45.—The names of members elected as General Officers and members of the Council for the year 1944-45 are given on page ii.

VERKIESING VAN ALGEMENE AMPSDRAERS EN RAADSLEDE VIR 1944-45.—Die name van die lede wat tot algemene Ampsdraers en Raadslede vir die jaar 1944-45 gekies is, kom voor op bladsy ii.

7. Mr. E. C. Chubb expressed his appreciation of the honour conferred on him by his election as President for the 1944-45 Session, and undertook to do all in his power to further the interests of the Association.

Mnr. E. C. Chubb het sy waardering uitgespreek vir die eer wat hom bewys is deur sy verkiesing tot President vir die 1944-45 Byeenkoms en het onderneem om alles in sy vermoë te doen om die belange van die Genootskap te bevorder.

8. SUBSCRIPTIONS OF ASSOCIATE AND STUDENT MEMBERS.—It was agreed to confirm the action of the Council in making the subscription for Associate Members for the 1944 Annual Meeting to be ten shillings and for Student Members to be five shillings instead of one pound and ten shillings and sixpence, respectively, it being noted that this action had been taken as a result of the curtailment of the Meeting to three days.

LEDEGELD VAN ASPIRANT- EN STUDENTLEDE.—Dit is ooreengekom om die handeling van die Raad, nl. die vasstel van ledegeld vir Aspirantlede vir die 1944-Jaarvergadering op tien sjielings en vir Studentlede op vyf sjielings, in plaas van een pond en tien sjielings en ses pennies respektiewelik, te bekragtig, terwyl aangeteken is dat hierdie besluit geneem is as gevolg van die verkorting van die Vergadering tot drie dae.

9. ESTABLISHMENT OF STATE FILM INSTITUTE.—On the proposal of Dr. A. Pijper, seconded by Dr. J. I. Quin, the following resolution was adopted and referred to the Council for action—

"The South African Association for the Advancement of Science, considering the growing importance of the motion picture film in Science and Education, and the need for locally produced films of South African scientific enterprises under South African

conditions, and being aware of the lack of facilities for the production of such films, urges the Union Government to establish a State Film Institute, with the following functions:—

(1) to maintain a technical staff and equipment capable of making such films under the direction of scientific institutions,

(2) to advise and assist scientific workers in the making of such films,

(3) to serve as a national and international bureau for the exchange, acquisition and distribution of such films."

OPRIGTING VAN STAATS-ROLPRENTINSTITUUT.—Op voorstel van Dr. A. Pijper, gesekondeer deur Dr. J. I. Quin, is die volgende besluit aangeneem en na die Raad verwys vir behandeling:—

"Die Suid-Afrikaanse Genootskap vir die Bevordering van Wetenskap, met die oog op die toenemende belangrikheid van die bioskoop-rolprent in wetenskap en onderwys, en die behoefte aan plaaslik-vervaardigde rolprente van Suid-Afrikaanse wetenskaplike ondernemings onder Suid-Afrikaanse toestande, en bewus van die gebrek aan geleenthede vir die vervaardiging van sulke rolprente, dring by die Regering aan op die oprigting van 'n Staats-Rolprentinstituut, met die volgende bedrywighede:—

(1) 'n tegniese personeel en uitrusting te onderhou, wat in staat is om sulke rolprente, onder die bestuur van wetenskaplike inrigtings, te vervaardig,

(2) wetenskaplike werkers raad en hulp te gee by die vervaardiging van sulke rolprente,

(3) as 'n nasionale en internasionale buro te dien vir die ruil, koop en versprei van sulke rolprente."

10. PRESERVATION OF ELEPHANTS AND CAPE BUFFALO IN THE ADDO RESERVE.—On the proposal of Dr. Austin Roberts, seconded by Dr. G. de Kock, the following resolution was adopted and referred to the Council:—

"The South African Association for the Advancement of Science desires to draw the attention of the Union Government to the urgent need for preserving the relics of the elephants in the Addo Reserve in the Cape Province, and strongly urges that steps be taken to confine these elephants within the reserve in such an effective way that they will not constitute a menace to neighbouring farmers and at the same time with a sufficiently large feeding area as to ensure their survival and perpetuation. Within the present reserve are also the last of the typical Cape Buffalo, and the area should not therefore be reduced, should a portion of the area be specially set aside experimentally for the Addo Elephants."

BEHOUD VAN OLIFANTE EN KAAPSE BUFFELS IN DIE ADDO-WILDTUIN.—Op voorstel van Dr. Austin Roberts, gesekondeer deur Dr. G. de Kock, is die volgende besluit aangeneem en na die Raad verwys:—

"Die Suid-Afrikaanse Genootskap vir die Bevordering van Wetenskap wens die aandag van die Unie-Regering te vestig op die dringende noodsaaklikheid vir die behoud van die oorblyfsels van die olifante in die Addo-Wildtuin in die Kaap-Provinsie en dring sterk daarop aan dat stappe gedoen word om hierdie olifante in die wildtuin in te sluit op so'n doeltreffende manier dat hulle geen gevaar vir naburige boere oplewer nie en terselfdertyd met 'n voldoende groot weigebied om hulle behoud en voortbestaan te verseker. In die huidige wildtuin is ook die

oorblyfsel van die tiepiese Kaapse Buffel en die gebied behoort daarom nie kleiner gemaak te word as 'n stuk daarvan spesiaal, bywyse van proefneming, vir die Addo-olifante gereserveer word nie."

11. ANNUAL MEETING—1945.—In view of the International situation, it was agreed that the Council have power to decide the date, duration and venue of the 1945 Annual Meeting.

JAARVERGADERING—1945. — Met die oog op die internasionale omstandighede is besluit dat die Raad mag sal hê om die datum, duur en plek van die 1945-Jaarvergadering vas te stel.

12. VOTES OF THANKS.—On the proposal of Mr. E. C. Chubb, a unanimous vote of thanks was accorded firstly to the Associated Scientific and Technical Societies of South Africa for providing the necessary accommodation for the holding of the Annual Meeting in Kelvin House, and for granting the privilege of Honorary Membership to visiting members attending the meeting, secondly to the Honorary Auditors, Messrs. Alex. Aiken and Carter, for their services in carrying out the audit for the year 1943/44, thirdly to the Press for their services in reporting the proceedings of the Annual Meeting, and finally to the Witwatersrand Local Centre for hospitality at the meeting.

Dr. H. E. Wood proposed a hearty vote of thanks to the President (Colonel J. G. Rose) for the valuable services he had rendered the Association during his term of office and to Dr. T. D. Hall (Vice-President) for conducting those Council Meetings held during the year which the President had been unable to attend owing to his being resident in Cape Town, this vote of thanks being carried with acclamation.

Colonel Rose and Dr. Hall expressed their appreciation of the vote of thanks accorded them.

MOSIE VAN DANK.—Op voorstel van Mnr. E. C. Chubb is eenparig die dank van die vergadering gebring, in die eerste plek aan die Verenigde Wetenskaplike en Tegniese Verenigings van Suid-Afrika, vir die Verskaffing van die nodige geleentheid vir die hou van die Jaarvergadering in Kelvin-Huis en vir die verleen van Ere-Lidmaatskap aan besoeker-lede van die Vergadering; in die tweede plek aan die Ere-Ouditeure, die firma Alex. Aiken en Carter, vir hulle gedienstige ouditering vir die jaar 1943-44, in die derde plek aan die Pers vir sy verslae van die verrigtings van die Jaarvergadering, en tenslotte aan die Witwatersrandse Plaaslike Sentrum vir die gasvryheid aan die Vergadering verleen. .

Dr. H. E. Wood het 'n mosie van hartlike dank aan die President (Kol. J. G. Rose) voorgestel vir sy waardevolle dienste wat hy gedurende sy ampstyd aan die Genootskap bewys het, en aan Dr. T. D. Hall (Vise-President) vir die leiding van daardie Raadsvergaderings gedurende die jaar, wat die President, weens sy verblyf in Kaapstad, nie kon bywoon nie. Hierdie mosie is met toejuiging aangeneem.

Kolonel Rose en Dr. Hall het hulle waardering uitgespreek vir die mosie van dank, wat op hulle uitgebring is.

REPORT OF COUNCIL FOR YEAR ENDING 30TH JUNE, 1944.
VERSLAG VAN DIE RAAD VIR DIE JAAR TOT OP 30 JUNIE, 1944.

1. OBITUARY/IN MEMORIAM.—Your Council reports with regret the deaths of the following members/U Raad gee met leedwese kennis van die oorlyde van die volgende lede.—His Excellency Sir Patrick Duncan, Mr. A. Affleck, Mr. N. O. Curry, Mrs. I. Gilchrist, Mrs. J. D. Rheinallt Jones, Professor H. L. Malherbe and Professor A. I. Perold.

2. MEMBERSHIP.—Since the last Report, fifty members have joined the Association; seven have died and two have resigned, and the names of three members have been removed from the membership list.

The following table shows a comparative list of the geographical distribution of membership as at the 30th June, 1943, and the 30th June, 1944:—

LEDETAL.—Sedert die jongste verslag het vyftig lede by die genootskap aangesluit, sewe is oorlyde en twee het bedank. Die name van drie lede is van die ledelys geskrap. Die volgende lys toon, vergelykenderwys, die geografiese voorkoms van lede op 30 June, 1943 en 30 Junie 1944:—

	1943	*1944*
Transvaal	333	364
Cape of Good Hope	154	158
Natal	70	72
Orange Free State	19	21
Southern and Northern Rhodesia ..	11	11
South-West Africa	1	2
Moçambique	2	2
Abroad	22	20
	612	650

3. THE JOURNAL.—Volume XL of the "South African Journal of Science," being the Annual Report of the Association for the year ending 30th June, 1943, was circulated to members in December, 1943. It consisted of 426 pages and contained the seven Presidential Addresses and forty other papers in full or in abstract, together with Indexes, Accounts, etc.

DIE "JOURNAL."—Deel XL van die Suid-Afrikaanse Journal van Wetenskap, wat die jaarverslag van die Genootskap vir die jaar tot op 30 Junie 1943 bevat, is in Desember 1943 aan die lede voorgelê. Dit het uit 426 bladsye bestaan en het die sewe Voorsitterstoesprake en 40 lesings, volledig of in abstracto, benewens inhoudsopgawe, rekeninge, ens., bevat.

4. QUARTERLY BULLETINS.—Four Bulletins were issued during the year under review, in July, 1943, and in January, May and June, 1944, respectively.

KWAARTAAL-BULLETINS. — Gedurende die jaar is vier bulletins uitgegee, respektiewelik in Julie 1943, en Januarie, Mei en Junie 1944.

5. SOUTH AFRICA MEDAL AND GRANT/SUID-AFRIKA-MEDALJE EN SKENKING, 1944.—Your Council has awarded the South Africa Medal, together with a grant of £43 4s. 10d., to Professor C. van Riet Lowe. The recommendation was made by the Medal Committee, consisting

of the following:—U Raad het die Suid-Afrika-Medalje saam met 'n skenking van £43 4s. 10d. toegeken aan Professor C. v. Riet Lowe. Die aanbeveling is gedoen deur die Medalje-Komitee, bestaande uit die volgende lede:—

Dr. T. D. Hall (Chairman), Professor A. W. Bayer, Dr. S. F. Bush, Professor C. G. S. de Villiers, Dr. A. L. du Toit, Dr. P. J. du Toit, Professor P. R. Kirby, Professor W. J. Lutjeharms, Professor I. D. MacCrone, Professor L. F. Maingard, Dr. A. Pijper and Dr. H E. Wood. The Secretary of the British Association has been notified of the award.

Die Sekretaris van die Britse Genootskap is van die toekenning in Kennis gestel.

6. British Association Medal, 1944.—No entries were received.

Geen inskrywings is ontvang nie.

7. Donations/Gifte.—The thanks of the Association are due to the Honourable the Minister of Finance and of Education for a grant of £250 towards the expenses of the publication of the Journal, and to the Johannesburg Municipality for a grant of £100.

Die Genootskap spreek sy dank uit aan Sy Ed. die Minister van Finansie en Onderwys vir 'n gif van £250 tot die onkoste van die uitgawe van die Journal, en aan die Johannesburgse Munisipaliteit vir 'n toelae van £100.

8. U.S.S.R. Academy of Science and Soviet Scientists Anti-Fascist Committee.—A number of cables have been received from Moscow, some containing friendly greetings, others dealing with scientific achievements in the Soviet Union since the outbreak of war. Abstracts of these latter have appeared in the Bulletin.

U.S.S.R. Akademie van Wetenskappe en Soviet-Wetenskaplikes Anti-Fascist-Komitee.—'n Aantal kabelgramme is uit Moskou ontvang, sommige met vriendskaplike groete ander oor wetenskaplike suksesse in die Soviet-Unie sedert die begin van die oorlog.

9. Resolutions Adopted by Annual General Meeting, 29th June, 1943:

(a) *Protection and control of the fauna, flora and sanctuaries in South Africa.*—The various issues embodied in this Resolution have been investigated by a Committee of Council. The Council has been in communication with the Honourable the Minister of Lands and negotiations are still proceeding.

(b) *Area including the great caves of Makapans to be set aside as a Nature Reserve.*—This Resolution was forwarded to the Honourable the Minister of the Interior.

(c) *General extension of research activities in the Union of South Africa.*—Council appointed a Committee to collect information regarding the actual expenditure on research by organisations in South Africa that undertake such work. The Committee was not successful and Council decided that without such factual evidence, which could be compared with information regarding expenditure in other countries, it would be advisable not to approach the Government at the present moment.

Besluite Aangeneem deur die Algemene Jaarvergadering, 29 Junie. 1943.

(a) *Beskerming en beheer van die fauna, flora en sanctuaria in Suid-Afrika.*—Die verskillende punte wat in hierdie besluit beliggaam is, is deur 'n Komitee van die Raad ondersoek. Die Raad het met Sy Edele die Minister van Lande in verbinding getree en onderhandelinge duur nog voort.

(b) *'n Gebied, wat die groot grotte van Makapans insluit, as 'n Natuurlike Wildtuin af te sonder.*—Hierdie besluit is aan Sy Edele die Minister van Binnelandse Sake gestuur.

(c) *Algemene uitbreiding van Navorsingswerk in die Unie van Suid-Afrika.*—Die Raad het 'n Komitee aangestel om informasie in te win betreffende die eintlike uitgawe aan navorsingswerk deur organisasies in Suid-Afrika wat sulke werk onderneem. Die Komitee was nie suksesvol nie en die Raad het besluit dat dit, sonder hierdie gegewens wat met informasie oor uitgawe in ander lande vergelyk sou kon word, nie raadsaam sou wees om die Regering op die oomblik te nader nie.

10. ANNUAL MEETING, 1944.—As in the last few years, your Council arranged a short session in Johannesburg for the three days July, 3rd 4th and 5th. A symposium on "A Scientific Approach to the Problems of Post-War Employment" forms the programme for the third day

JAARVERGADERING 1944.—Soos in die laaste paar jaar het u Raad 'n kort sitting in Johannesburg georganiseer vir die drie dae 3, 4 en 5 Julie. 'n Simposium oor "'n Wetenskaplike nadering van die Probleme van Na-oorlogse werk" vorm die program vir die derde dag

11. THE NEW COUNCIL.—On the basis of membership provided in the Constitution, Section 22, the number of members of Council assigned to each Centre during the ensuing year should be as follows:

Die aantal Raadslede vir elke sentrum gedurende die volgende jaar, moet, soos in die Statute, Artikel 22, bepaal, op die basis van die ledetal as volg verdeel word:—

Transvaal:	
Witwatersrand	16
Pretoria	6
Outside	1
Province of the Cape of Good Hope:	
Cape Peninsula and Outside	6
Stellenbosch and District ..	2
East London and Port Elizabeth	1
Grahamstown, Kingwilliamstown and District ..	1
Kimberley	1
Oudtshoorn	1
Outside .	1
Natal:	
Durban . .	3
Pietermaritzburg and Outside Districts ..	2
Orange Free State:	
Bloemfontein ..	1
Southern Rhodesia .	1
	43

12. HONORARY AUDITORS.—Messrs. Alex. Aiken and Carter, our Honorary Auditors for many years, have audited the Accounts of the Association for 1943-44, and the thanks of the Association are due to them for this service.

ERE-OUDITEURS.—Die firma Alex. Aiken en Carter, ons Ere-Ouditeurs sedert vele jare, het die Rekeninge van die Genootskap vir 1943-44 geouditeer en die Genootskap betuig sy dank vir hierdie dienste

13. SECRETARIAT.—Your Council thanks the Associated Scientific and Technical Societies of South Africa for their services as Assistant General Secretaries of the Association, and wishes specially to record their appreciation of the valuable help of Mr. A. J. Adams and Mr. I. M. Sinclair.

SEKRETARIAT.—U Raad dank die Verenigde Wetenskaplike en Tegniese Verenigings van Suid-Afrika vir hulle dienste as Assistent-Algemene Sekretarisse van die Genootskap en wil spesiaal sy waardering boekstaaf van die waardevolle hulp van Mnr. A. J. Adams en Mnr. I. M. Sinclair.

REPORT OF THE HONORARY GENERAL TREASURER FOR THE YEAR ENDED 31st MAY, 1944.

In my report last year, I drew attention to increased expenditure which would have to be met this year in connection with Secretarial Fees and Printing Charges, and the Income and Expenditure Account now before you shows that the Secretarial Fees have increased by £55 and JOURNAL expenses are £139 greater. Under these circumstances, with an income similar to that of last year, a deficit of £33, as against a previous profit of £173, is not surprising.

It may be remarked that a small additional expense in printing was incurred by putting into effect the first stage of the policy of making the Association fully bilingual, and I am satisfied that expenditure in this connection will not be begrudged.

We continue to receive financial support from the Union Department of Education and from the City Council of Johannesburg, and to these generous donors we would again express our gratitude for their recognition of our work in furthering the Advancement of Science in South Africa.

JAS. GRAY,

Honorary General Treasurer.

VERSLAG VAN DIE ERE-ALGEMENE PENNINGMEESTER VIR DIE JAAR TOT OP 31 MEI 1944.—In my verslag van verlede jaar het ek die aandag gevestig op groter uitgawe wat hierdie jaar betaal moes word, in verband met sekretariaat-honorarium en drukkoste, en die Inkomste- en Uitgawerekening wat nou aan U voorgelê is toon aan dat Sekretariaat-honorarium £55 en die Joernaalkoste £139 hoër is. Onder hierdie omstandighede, met inkomste gelyk aan die van verlede jaar, was 'n nadelige saldo van £33, teen 'n vorige voordelige saldo van £173, te verwag.

Ek wil hier opmerk dat 'n klein ekstra uitgawe in drukwerk veroorsaak is deur die ten uitvoer bring van die eerste stadium van ons beleid om die Genootskap ten volle tweetalig te maak en ek is daarvan oortuig dat hierdie ekstra uitgawe as geregverdig beskou sal word.

Ons ontvang nog altyd geldelike steun van die Unie-Departement van Onderwys en die Staadsraad van Johannesburg en ons wil hierdie milde gewers weer ons dank betuig vir hulle waardering van ons werk in die bevordering van wetenskap in Suid-Afrika.

(Get.) JAS. GRAY,

Ere-Algemene Penningmeester.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

BALANCE SHEET AT 31st MAY, 1944.

LIABILITIES.

Sundry Creditors:		
General Accounts	£47 13 10	
Grants to Local Centres under Rule 35	43 15 6	
Recipient South Africa Medal Award, 1944	43 4 10	
Subscriptions paid in advance	13 7 0	
Endowment Fund	42 2 7	
		£190 3 9
Library Binding and Equipment Account:		
Balance at 31st May, 1943 ...	181 7 2	
Add—Interest from Library Endowment Fund	73 17 9	
	255 4 11	
Less—Expenditure during year	37 11 4	
		217 13 7
Income and Expenditure Account:		
Balance at 31st May, 1943 ...	833 4 1	
Less—Excess of expenditure over Income for the year ended 31st May, 1944	33 8 3	
		799 15 10
		1,207 13 2
Endowment Fund		3,274 14 5
Library Endowment Fund		2,164 11 6
South Africa Medal Fund		1,670 9 1
British Association Medal Fund		498 17 3
		£8,816 5 5

ASSETS.

Cash:		
At Bank	£170 10 10	
At Post Office Savings Bank, with Interest accrued	39 17 7	
At United Building Society, St. Andrew's Branch, with Interest accrued	950 7 2	
		£1,160 15 7
Sundry Debtors:		
Library Endowment Fund	3 17 9	
South Africa Medal Fund ...	1 9	
For Reprints of Papers, etc ..	13 0 9	
		17 0 3
Furniture:		
Balance at 31st May, 1943	33 19 6	
Less—Depreciation	6 16 0	
		27 3 6
Medals on Hand		2 13 10
		1,207 13 2
Trustees—Endowment Fund . As per separate Account.		3,274 14 5
Library Endowment Fund . As per separate Account.		2,164 11 6
Trustees—South Africa Medal Fund . . As per separate Account.		1,670 9 1
Trustees—British Association Medal Fund .. As per separate Account.		498 17 3
		£8,816 5 5

We have examined the books, accounts and vouchers of The South African Association for the Advancement of Science for the year ended 31st May, 1944, and have obtained all the information and explanations we have required. We have satisfied ourselves of the existence of the securities. Proper books and accounts have been kept. In our opinion the above Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of affairs of the Association at the 31st May, 1944, according to the best of our information and the explanations given to us and as shown by the books of the Association as at 31st May, 1944.

Johannesburg, 14th June, 1944.

ALEX. AIKEN & CARTER, Auditors.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1944.

Dr.

To Secretarial Fees			£240 0 0
,, Journal Expenses		£854 14 0	
Less—			
Government Grant	£250 0 0		
Johannesburg Municipal Grant	100 0 0		
Sales, Reprints and Advertisements	135 6 6		
		485 6 6	
			369 7 6
,, Stationery and Printing ...			42 10 10
,, Postages			26 11 3
,, Sundry General Expenses ...			16 0 2
,, Grants to Local Centres under Rule 35:			
Witwatersrand		27 18 0	
Cape of Good Hope ...		9 12 0	
Natal		6 5 6	
			43 15 6
,, Depreciation on Office Furniture			6 16 0
,, Pension—H. A. G. Jeffreys			90 0 0
			£835 1 3

Cr.

By Annual Subscriptions	£600 2 6	
,, Arrear Subscriptions	53 17 0	
,, Associates' Fees	1 10 0	
,, Students' Fees	1 5 0	
		£656 14 6
,, Interest:		
From Endowment Fund ...	126 9 11	
United Building Society, St. Andrew's Branch, Savings Account	17 9 6	
Post Office Savings Bank Account	0 19 1	
		144 18 6
,, Balance, being Excess of Expenditure over Income, for the year ended 31st May 1944		33 8 3
		£835 1 3

We report that to the best of our knowledge and belief, and on the information supplied to us the above account reflects a true statement of the income and expenditure of the Association for the year ended 31st May, 1944.

Johannesburg,
14th June, 1944.

ALEX. AIKEN & CARTER,
Auditors.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

ENDOWMENT FUND.

Dr. INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1944. Cr.

Dr.	£ s. d.	Cr.	£ s. d.
To Interest, as per contra, transferred to General Fund	£126 9 11	By Interest received during the year . .	£126 9 11
,, Balance, transferred to Accumulated Funds	58 0 0	,, Life Membership Subscriptions	58 0 0
	£184 9 11		£184 9 11

BALANCE SHEET AS AT 31st MAY, 1944.

Liabilities.			Assets.		
Accumulated Funds—			Investments in hands of Trustees—		
Balance at 31st May, 1943 ...	£3,216 14 5		Cape Town Municipality 3¾% Stock	£1,150 0 0	
Add—Amount transferred from Income and Expenditure Account	58 0 0	3,274 14 5	Cape Town Municipality 4% Stock	300 0 0	
			Cape Town Municipality 5% Stock	240 0 0	
			Cape Town Municipality 5% Stock	800 0 0	
			Port Elizabeth Municipality 3½% Stock	100 0 0	
			Cape of Good Hope Savings Bank	642 11 10	3,232 11 10
			Amount due from General Fund		42 2 7
		£3,274 14 5			£3,274 14 5

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

LIBRARY ENDOWMENT FUND.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1944.

Dr.	£ s. d.	Cr.	£ s. d.
To Balance, transferred to Library Binding and Equipment Account	£73 17 9	By Interest received during the year.	£73 17 9
	£73 17 9		£73 17 9

BALANCE SHEET AT 31st MAY, 1944.

Liabilities.	£ s. d.	Assets.	£ s. d.
Amount due to General Fund	£3 17 9	Investments—	
Accumulated Funds—		£2,000 City of Johannesburg $3\frac{1}{2}$% Local Registered Stock 1965—at cost	£1,970 0 0
Balance at 31st May, 1943	2,164 11 6	Cash at United Building Society, St. Andrew's Branch—Savings Bank Account ...	198 9 3
	£2,168 9 3		£2,168 9 3

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SOUTH AFRICA MEDAL FUND.

Dr. INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1944. Cr.

To Expenses in connection with 1944 Award ...	£6 16 6	By Interest received during the year	£50 1 4
,, Amount of 1944 Award	43 4 10		
	£50 1 4		£50 1 4

BALANCE SHEET AT 31st MAY, 1944.

Liabilities.		Assets.	
Amount due to General Fund	£0 1 9	Investments in hands of Trustees—	
Accumulated Funds—		Fixed Deposit, South African Permanent Mutual Building and Investment Society ...	£1,666 0 1
Balance at 31st May, 1913.	1,670 9 1	Post Office Savings Bank	4 10 9
	£1,670 10 10		£1,670 10 10

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE BRITISH ASSOCIATION MEDAL FUND.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1941.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Award	£20	0	0	By Interest received during the year	£17	17	6
				,, Balance, transferred to Accumulated Funds	2	2	6
	£20	0	0		£20	0	0

BALANCE SHEET AT 31st MAY, 1941.

Liabilities.	£	s.	d.	£	s.	d.	Assets.	£	s.	d.
Accumulated Funds—							Investments in hands of Trustees—			
Balance at 31st May, 1943 ...	£500	19	9				£450 Union of South Africa 3½% Local Registered Stock 1948/58.	£450	0	0
Less — Amount transferred from Income and Expenditure Account	2	2	6				Post Office Savings Bank	48	17	3
				498	17	3				
				£498	17	3		£498	17	3

REPORT OF THE HONORARY LIBRARIAN FOR THE YEAR ENDED 30th JUNE, 1944.

VERSLAG VAN DIE ERE-BIBLIOTEKARIS VIR DIE JAAR GEEINDIG 30 JUNIE 1944.

The Association's Library is housed in the Library of the University of the Witwatersrand, Johannesburg.

Die Genootskap se Biblioteek word in die Biblioteek van die Universiteit van die Witwatersrand, Johannesburg gehuisves.

HOURS OF OPENING:

Weekdays:

Term: 8.30 a.m. to 6 p.m.
Vacation: 9 a.m. to 5 p.m.

Saturdays:

Term: 8.30 a.m. to 12.30 p.m.
Vacation: 9 a.m. to 12.30 p.m.

URE:

Weekdae:

Semester: 8.30 v.m. tot 6 n.m.
Vakansie: 9 v.m. tot 5 n.m.

Saterdae:

Semester: 8.30 v.m. tot 6 n.m.
Vakansie: 9 v.m. tot 5 n.m.

EXCHANGE OF PUBLICATIONS.—During the year the following names were added to the exchange mailing list:—

RUILING VAN PUBLIKASIES.—Gedurende die jaar is die volgende name aan die ruilings-adreslys bygevoeg:—

Association des ingenieurs, Elisabethville.

Estacao agronomica nacional quinta da Aldeia, Portugal.

Facultad de agronomio y veterinaria, Buenos Aires.

Reading public museum and art gallery, Pa.

Royal Society of Canada, Ottawa.

DONATIONS are gratefully acknowledged to the following:—

GESKENKE word aan die volgende dankbaar erken:—

Australia: Council for scientific and industrial research.
Hill, G.F.: Termites from the Australia region.

British museum (Natural history):
Economic series Nos. 2a, 5, 15.
John Murray expedition, 1933/34. Scientific reports, Vols. 2, No. 2; 4, No. 9; 5, Nos. 1-6.

Smart. J.
Insects of Medical Importance.

Dr. R. T. Lawrence, Director, Natal museum:
South African Journal of Science, Vols. 12-38, 1915-42.

Mr. B. M. Narbeth:
South African Journal of Science, Vol. 17, No. 1, and 18, Nos. 1-2.

Colonel W. H. W. Young:
South African Journal of Science, Vols. 33, 36,-39.

STOCK.—The Library now contains about 3,700 volumes, and 185 different titles are received currently.

VOORRAAD.—Die Biblioteek besit nou omtrent 3,700 bande en 185 verskillende titels word lopend ontvang.

SOUTH AFRICAN JOURNAL OF SCIENCE.—The Library continues to store the stock of the JOURNAL and to supply individual volumes for which orders are received. Apart from exchanges and sales, various publications of the Association were supplied on request to Australia House, the Indian Science Congress Association, and the Royal Society of New Zealand.

SUID-AFRIKAANSE JOERNAAL VAN WETENSKAP.—Die Biblioteek bewaar nog steeds eksemplare van die JOERNAAL en verskaf individuele bande waarvoor bestellinge ontvang word. Apart van ruilings en verkopings, is verskeie publikasies van die Genootskap aan Australia House, Indian Science Congress Association en Royal Society of New Zealand op versoek gelewer.

ACCESSIONS TO SERIAL PUBLICATIONS/AANWINSTE TOT PERIODIEKE PUBLIKASIES, 1943/44.

Agronomia Lusitana. 1, 1939+.

Australia. Council for scientific and industrial research.
Corrosion circular. 1, 1940+.
Industrial chemistry circular. 1, 1942+.

Buenos Aires. Universidad. Facultad de agronomia y veterinaria.
Jornados agronomicas y veterinarias. 1937, 1939, 1941+.

Harvard university. Museum of comparative zoology.
Annual report. 1941/42+.
Bulletin. 90, 1942+.

Royal society of New South Wales.
Journal of proceedings. 64, 1930+.

For a Catalogue of serial publications in the Library, and Supplement, see this JOURNAL, Vol. 30, pp. xxv-xxix, and Vol. 34, pp. xxxiv-xxxvii. Subsequent accessions are listed in the Annual report.

Vir 'n Katalogus van periodieke publikasies in die Biblioteek en Supplement, sien hierdie JOERNAAL, Band 30, b. xxv-xxix, en Band 34, b. xxxiv-xxxvii. 'n Lys van latere aanwinste word in die Jaarlikse Verslag gegee.

The Hon. Librarian edited for the National Research Council and National Research Board "Catalogue of Union Periodicals, Vol. 1, Science and Technology." Johannesburg, 1943. xvi, 525 p. Titles in the Library are incorporated and marked "JS243." Price (post free): Africa, 15s., Overseas, 21s.

Die Ere-Bibliotekaris het vir die Nasionale Adviserende Navorsingsraad en Nasionale Navorsingsraad geredigeer: "Catalogue of Union Periodicals, Vol. 1, Science and Technology." Johannesburg, 1943, xvi, 525 b. Titels in die Biblioteek word ingelyf en "JS243" gemerk. Prys (posvry): Afrika 15s., Oorsee 21s.

P. FREER,
Hon. Librarian/Ere-Bibliotekaris.

University of the Witwatersrand/Universiteit van die Witwatersrand,
Johannesburg.

12th June, 1944.

South African Journal of Science, *Vol. XLI, pp. 1-9, February, 1945.*

THE ADVANCEMENT OF SCIENCE

BY

Col. J. G. Rose,

President.

President's Address, delivered 3rd July, 1944.

I have taken as the title for this address the words which describe the object of our Association—"The Advancement of Science"—because the present appears to be an appropriate period for reflection on the work the Association has done and on that which it still must do.

When this Association was formed, science, as now known, was in its infancy in South Africa. higher education was still for the few, and industry for the most part employed methods untrammelled by scientific control. The few scientists of those days realised the importance of science in every day' life and the need for encouraging the discovery of new methods to increase efficiency and so ease the burden of labour. Some of them hit upon the idea of forming groups of interested persons, consisting both of laymen and of scientists, whose duty it would be to introduce science to industry and to the people as a whole, and to encourage and aid those investigators working to discover and develop new and improved methods and new truths. And so our Association was born.

Here we may ask what is this science that we still seek to advance? Judging by its derivation, science is a synonym for knowledge, and we may justly be considered an Association for the advancement of knowledge. But with that characteristic for which our language is famous, and which continually enriches it, science has come to mean something a little more than mere knowledge. It suggests accurate and proved knowledge, knowledge that can be relied upon, knowledge that can be applied with certainty to produce desired results, or used with confidence to base plans and calculations upon in order to make further advances. Science is, of course, not wisdom any more than knowledge is. Many a one of us may have much knowledge or science and yet have little wisdom! Knowledge we can gain in many ways, but wisdom is mostly a priceless gift. We either have it or we have it not—though we can develop and utilize so much of it as we possess, by study. observation, and experience. Wisdom may be found in the experience of the past, but not in the inexperience of the future.

How, then, have we fulfilled our ideal of the advancement of accurate knowledge in the years which have elapsed since this Association was founded? Like other similar bodies

throughout the world, we have used the lecture, the address, the presentation and publication of papers, to the best of our ability and opportunities. We have had most valuable aid from the Press, we have been encouraged by the Government, and many workers in both pure and applied science have given unstintingly of their time and skill to assist in spreading useful knowledge in every possible way. Latterly the cinema has also contributed its share and will certainly do so to a greater extent in the near future, as its technique and facilities become better known among scientific workers. I belive that posterity will say that we have worked well and that our efforts, puny though they may seem to some of us, have not been unsuccessful.

It is not so very long ago that the pursuit of knowledge for practical purposes and its application to everyday life was considered to be not the best way to spend your time, as the following incident will show.

When Sir David Gill, a past president of this Association, retired from his office as His Majesty's Astronomer at the Cape, he was given a farewell dinner. The chairman was John X. Merriman, then, if I remember rightly, Premier of the Cape. Merriman, it will be remembered, was the Premier who balanced his budget at the time of Union by cutting the salaries of his Civil Servants (with whom he had a vendetta of long standing), rather than by employing the usual orthodox methods. He was a politician of great culture and considerable influence, but had no practical bent whatsoever. A great believer in education, he was of the classical school and held that knowledge should be acquired for social purposes only, as one would get the latest thing in ties or shoes! Never should it be applied for practical purposes! He knew nothing very much of astronomy, but admired Gill greatly because he was a world-famous man in his profession; and because no practical application of his work was known to Merriman. And so in his valedictory speech, he eulogised Gill as a man who sought knowledge purely for its own sake. Amongst many other things I have forgotten, he said, "Sir David is not a man who invents telegraphs, telephones, motor cars and other modern nuisances! His mind is far above such petty things. He sits up night after night counting the stars, simply because he wants to know accurately how many of them there are! He measures their enormous distances merely to make sure that the visible universe is the gigantic thing it has been made out to be"—and so on, in the cultured and fluent speech that was so characteristic of him. Gill, who was intensely practical in every way, got more and more restive as the speech proceeded. When, eventually, he rose in reply, he forgot all the nice things he had intended to say about the Cape and its people, and regaled us with the finest lecture on the practical application of astronomy it has ever been my good fortune to hear! Merriman's outlook on science and research has been replaced by a wider vision, as

the value of science came to be better understood. To-day we have almost passed to the other extreme, as the swinging pendulum of progress seeks ever the position of rest it never finds! For the present that is perhaps as well, at any rate, until the world has been healed of its wounds and we, once more, have time for the pleasures of quiet contemplation.

We meet again under the dark clouds of war, though now those clouds show their silver linings and the east is brightening with the promise of the coming day of peace. But the time for the resumption of normal working throughout this vast yet empty country of ours is not yet.

As scientists, the events of the war should make us both sad and proud! Sad, because modern science alone has made possible this so-called " Total War " of destruction. The misapplication and prostitution of the wonderful gifts of science, given to the world with such great eagerness and hope, make us sorrowful beyond expression. But we are proud also, because our scientists have wrought tirelessly and unceasingly to keep our nation ahead of our enemies in the production of new and better methods of attack, and they have not laboured in vain.

The word " defence " is not employed in this connection, because all soldiers know, only too well, that attack is by far the best method of defence! For if you are attacked by evil you must destroy that evil if you are to have the blessing of lasting peace. Mere defence can never achieve that object. And so we note with pride and relief that our scientists are well ahead of those of our enemy. Never has the enemy sprung a surprise that our men have not swiftly and completely countered —the reverse, however, has often been the case. There is evidence also that some deterioration may have set in, perhaps years ago, amongst enemy scientists. It would be unwise to dwell in detail upon this or any other aspect of science in war, while the enemy is ever on the watch for any hint of our position —or of his own as seen by us—but we have been regaled *ad nauseam* in years gone by with tales of the superiority of German scientists over our own or, indeed, over any other scientists in the world, so that it would appear not unreasonable to call attention to a minor, yet interesting detail of the naval action at the River Plate, which points in the direction indicated. The German pocket battleship, which was so heavily defeated in that action, had the advantage of speed and was armed with eleven inch guns—her opponents' guns were only six inch. All the rules of naval warfare made it possible for the German ship to sink her opponents long before they could get close enough to score even a hit upon her. Why, then, did she fail to do so? Hidden away in an obscure corner of one of the many accounts of the action there appeared the statement that many shells from the German battleship passed clean through both sides of the British cruisers and fell into the sea beyond before exploding.

Now, it is a chemical problem of the very greatest severity and complexity to cause a shell, carrying a sensitive explosive of tremendous power, to pass intact through a given thickness of armoured plate and explode only at the instant it emerges into the hull beyond. The German chemists had solved this problem before 1914, actually before we had done so! Some of our most serious naval losses in the early stages of the last war were probably due to that fact. Yet in 1940, their shells often failed to do that which they had so triumphantly accomplished in 1915! Are the German chemists of to-day inferior to those of 1914? And did their failure to produce shells of 1914 standard give just that little extra assistance to the British ships, which enabled a well handled, but heavily out-classed six inch gun cruiser, manned though it was by the finest sailors in the world, to creep up close enough to her greatly superior opponent and inflict upon her a crippling defeat?

Anxiety to deny our enemy any hint of what our scientists have done and are doing for us, precludes much reference to their many triumphs. We must remember that in war time all armies have their listening posts, and these organisations jot down everything they hear—even the most trivial things are worth their attention. These reports are analysed and sorted out under their respective headings. One report may state, for example, that the location of enemy aeroplanes is an accomplished fact, thus confirming enemy suspicions born of many unfortunate experiences. Another speaks of radio location; yet another mentions that short waves rebound from planes and warships, and so on. Piecing all these together, the enemy knows with reasonable certainty that aeroplanes are located by means of a radio apparatus using short waves! He therefore pays particular attention to all captured radio apparatus and his scientists, sooner or later, are enabled to build their own sets to locate our planes. And here again let it be noticed in passing, that the enemy's sets when produced were much inferior to our own! It is always wisest, therefore, to refrain from any mention of our new inventions and so deny to the enemy some piece of vital information, some missing link, without which his scientists may be powerless to copy our work.

Careful readers of the daily Press will, however, see from time to time, reports of victories won with weapons that obviously show great advances upon those we had in 1939. They will notice also the complete failure of the enemy to produce any new secret weapon that even remotely answers to the optimistic predictions of enemy propaganda. It has been well said indeed that propaganda is the product of the proper goose! The enemy is affording ample proof of the accuracy of this statement. But, a word of warning! While enjoying a wise crack at the expense of propaganda, let us remember, and never forget that propaganda is a very powerful weapon when brought to bear upon that large body of people who are not

trained to think for themselves, or who are unable, for various reasons, to do so, or to distinguish the true from the false. The constant repetition of a statement by authority, or apparent authority, causes it to be believed unless it be countered in a manner similar to that used by its broadcaster. Deliberately deceitful and misleading, yet clever propaganda is a real danger. But, honest and accurate propaganda has its uses, and it may even be of service to us in the advancement of science.

And when peace comes what is our work to be? Originally, no doubt, the work of gaining knowledge appeared simple enough. But as science advances and knowledge accumulates, the work grows more complex. It becomes specialised. Professional groups come into being to deal with the details of their own particular science or industry and each one in its way becomes an association for the advancement of science. The world is well provided with scientific and professional bodies of all kinds, and the advancement of science goes on apace! When one contemplates all these things and notes the general application of the sciences in everyday life, it would seem as if the work of this and kindred associations has borne good fruit, and has reached a stage where a decline in their usefulness may set in. But science is knowledge, and of knowledge there is no end that we can see. The accumulation of knowledge is, moreover, to-day so great that it would appear time for us to pause a moment and consider whether we should not devote some of our time and energies to the application of some of this accumulated store of knowledge to the cause of humanity, as well as encouraging the search for something new. Knowledge should not end with its mere acquisition. It should be usefully employed in the service of mankind, or all the piled up knowledge of the past becomes a meaningless jumble and a vain toy. Knowledge is power; we have heard that phrase so often! But like a power station is must be set in motion, and its power made to flow to those who need it, before it can take its place among the useful things of the world!

It may be then, that research has to some extent overtaken the demand, and that much valuable and useful knowledge acquired in research is lying idle awating practical application. Is it not possible for us to assist in using it? Should not there be more investigation into this wealth of available knowledge?

The indexing of our journal so that the many valuable papers which have appeared therein may be readily found and referred to is a great and necessary step in this direction. The preparation of the index—a work of years—is proceeding steadily. When completed, it will rescue from oblivion many a useful contribution to the cause of science and the past work of this Association will be readily available for present and future workers. Nothing is more exasperating than the repetition, in ignorance, of work already done. If our index

saves even one worker from that unpleasant experience, it will have served its purpose well! Can this work not be extended, and a comprehensive index of existing work be added to our library?

The advancement of science is so bound up with research, that we should leave no stone unturned to encourage it. But how? There is a great deal of confused thinking in regard to research. On many, the word "research" has an effect similar to that produced by the word "mesopotamia" on the famous old lady of cherished memory. One so often meets with the idea that it is necessary merely to set up a research organisation, usually at the expense of the State, and all our problems are as good as solved. This may be a fine tribute by the layman to the powers of science, but unfortunately research is not as simple as all that. There is nothing more wasteful, nothing more harmful to science, nothing more productive of a sense of frustration, than ill organised research, whether it is conducted with the aid of grants, or in an institution organised without due care and experience The potterer is seen there at his best, fiddling about with the chemicals or instruments that he loves, quite unable to realise the high hopes which originally prompted his work.

All minds are not suited to research. Workers must be most carefully selected and encouraged if good results are to be achieved. And if the work is done in an institute, the head of the institute should be a man of wide experience in the practical application of science, and of the urgent needs of his day. He should be quick to appreciate what may be useful and what should be unhesitatingly rejected. The control of such work is, in the writer's opinion, safer in the hands of private industry than in the hands of the State. For a department of State labours under a great disability—perhaps the greatest of all—it has no means whereby it can quickly and certainly test in practice the true value of its work. It is also greatly hampered by cumbersome, yet most necessary rules and regulations. It is often disturbed by political considerations. Private companies are not so handicapped. They are responsible directly to experienced financiers, or to shareholders. The verdict of their balance sheet cannot be gainsaid. There the worker reads with certainty the success or failure of his efforts. No industry can hope to prosper for long if it be not supplied with a continual flow of new and tested knowledge. And in its balance sheet will appear the success or failure of its workers to maintain that necessary flow. The tendency to cast all burdens upon the State may be a form of indolence rather than impotence, but it augurs ill for the country. Carried to its logical conclusion, it means that eventually the State will do everything, and all, both good and bad, will be servants of the State. Laziness of thought and action will be fostered because

of the absence of all effective competition. Let science, at least, be free of this dangerous trend. Let it give a lead to that independence of thought and action whereby alone a country can progress and become great and prosperous. Let us deserve and maintain our sovereignty by our own efforts. All other ways lead to decadence, and eventually to the loss of our freedom and our right to rule to a greater and more virile people. Some of the most valuable research work is done in the laboratories controlling industry. Such work is usually simple investigation and can hardly be dignified by the name of research. But not infrequently difficult problems arise and their successful solution brings handsome dividends to the managers wise enough to know how to encourage and direct such research, and how to apply to the best advantage the rich prizes it often brings.

In research there must of necessity be much apparent waste of time, money and effort. There are many blind alleys down which we poor mortals must often travel in our search for the truth. For how can we be sure that the knowledge we seek does not lie hidden at the end of one of them? How can we be sure they are blind unless we follow them to the end?

Those who do research should ever seek the great simple laws of nature, bearing in mind that it is always the simple ideas and processes that are the most useful, and capable of the widest application. They are the most likely to conform to fundamental laws. Simplicity is a good watchword for those who engage in research, and it is remarkable how, with this object kept ever in mind, complicated processes may suddenly be by-passed, or resolved, like an algebraic formula, into a few simple operations.

The Sten gun is a case in point and as many of these useful weapons have, by now, been captured by the enemy, and as the War Office has released certain details of its construction, it may be mentioned here with something more than passing notice. When, after Dunkirk, our Expeditionary Force had returned battered, but anxious for further service, it was found that they had been obliged to leave behind them most of their equipment. This was perhaps a blessing in disguise, for most of it was old and obsolete, but its lack compelled concentration on its replacement in the shortest possible time with the best modern arms and equipment that the nation's resources could produce. At the same time it was realised amongst other things that a light gun after the pattern of the American "Tommy" gun—made famous by many a gangster of evil memory—or the German Schmeisser was a most necessary part of an army's weapons. But how, in the midst of all that feverish work on rearmament, was such a new weapon to be produced? Fortunately the design was there. Simplified to the greatest possible degree, it was possible to get the parts made even by ill equipped workshops and by keen amateur workers. Some workmen

merely drilled holes in bits of metal, others did nothing but cut slots, and most of this work was done in their " spare " time, after their heavy day's work had been done! So simple, however, was the design and so easy to produce, that a great flow of parts was obtained by this method. Arriving at the great central assembly workshops these various simple parts were rapidly assembled into hundreds of thousands of finished weapons without appreciable interruption to the ordinary work of rearmament, surely an outstanding example of the merits of simplicity in design! It is pleasant to record that the designers have not been forgotten. Of the letters of its name, S stands for Shepheard and T for Turpin, the two men to whom England owes the designing of this splendid weapon. The letters EN are the first two letters of England, the land of its birth. The name STEN, therefore, commemorates the designers and the country which produced it.

Encouragement of research seems very usefully and soundly attained by the correct use of grants-in-aid. These are applicable not only to the worker to whom a new line of thought, not of interest to his employers, has suddenly opened out in the course of his duties, but also to workers in pure science. These grants should be under strict and well informed control not only in the granting, but also during the course of the work to be done by their aid. In these days of urgency it is tempting to suggest that they should be granted only to workers in applied science. But here one is at once confronted with the fact that the discovery of radium was made as the result of research on the emanations of rays given off by uranium salts, the work being undertaken originally solely for the purpose of providing data upon which to base a thesis for a doctorate of science! "Humanity," said Madame Curie, " certainly needs practical men who get the most out of their work." But it also needs dreamers! Under the circumstances it is unwise to suggest any restrictions on the nature of research it is proposed to undertake. Decision should be left rather to a board of scientists specially chosen for their wide experience in both pure and applied science. Applicants should appear before this board, or its nominees, in person, and should be required to satisfy them as to the methods and objects of their proposed research.

Owing, largely, to the increasing employment of scientists in industry, it would appear that a widening gap has intervened between the workers in pure and applied science, to the disadvantage of both. For the worker in pure science is in possession of knowledge which may suggest new lines of attack on practical problems. In this Association of ours we have scientists of all kinds, and if we can discover some useful and practical bridge between the workers in pure and in applied science we shall be rendering a real service to mankind. Science will then be well co-ordinated and can devote all its resources to increase its

services to mankind. To assist in all this work let us use every endeavour to attract to our ranks the young scientist so that our work may be carried on with a vigour renewed each year by an influx of young blood. In a combination of old and young, any institution will find indefinite life and the surest progress. We can offer much to the young scientist, particularly that publicity which a journal can give so readily to his work. And if a yearly issue of our journal is not sufficient to meet the needs of impetuous youth, let us consider a more frequent issue, if by doing so we may increase our membership and help the young scientist on his way. Cut off from the experience that comes with age, the young scientist often travels long, dreary and unproductive roads. He may also pass unheeding the by-paths which lead to treasures of new knowledge, their junction with the main highway too indistinct for his still untrained eye. A little hint, a little nod, from experience, and he, too, will be off down those unexplored, mysterious ways, the opening up of which is the delight and the duty of all true scientists. And when he returns to the main highway where, alas, his bread and butter lies, and along which he must travel to reach those positions which all scientists have in view as their goal, whether he be successful in bringing back with him fresh knowledge, or whether he has merely found pleasant journeys or heavy climbing, or even wandered into a cul-de-sac, he will be the better and the richer for his experience, provided always that his steps have been those of the keen searcher and not those of the dawdler!

To the young research worker it usually appears as if all the easy things have long ago been discovered, all the most beautiful plums gathered. But it must not be forgotten that what looks easy to-day appeared unattainable to the workers of the past. As science advances it puts new weapons into the hands of its followers so that doors may be opened into places previously considered to be merely solid rock. And within those newly opened chambers there will be found newer and better tools so that the workers of to-morrow shall not be handicapped as compared with the workers of to-day.

Let us then, as an Association, not rest upon the achievements of the past. Especially while the war lasts, let us redouble our efforts, so that when youth returns all aglow and breathless from its victories in the field, it may find a live world waiting to receive it at home, and a warm welcome to employment in industries made ready for our soldiers by new discoveries and methods. So may they use their new found energies in the work of healing and reconstructing a world laid waste by the ravages of war, and so may they find that the work of those who had, perforce, to stay at home, has its value in the world just as much as that of those who bore the heat and burden of the day in the field.

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SPECTROCHEMICAL ANALYSIS AND ITS APPLICATION IN SCIENCE AND INDUSTRY

BY

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With 8 Text Figures.

Presidential Address to Section A, read 3rd July, 1944.

As far as I could ascertain, the President of a Section is expected to inform the Association of the advances of science in his particular field of interest. Although my research has been confined mainly to molecular spectra, I have decided to speak about "Spectrochemical Analysis and its Application in Science and Industry." In making this decision I thought of the large number of scientists present who would find it difficult to follow a rather specialised topic in physics such as molecular spectra and who would rather hear what methods physicists have developed in recent years to facilitate the work of other scientists in their own fields of interest. I also hoped to direct the attention of industry to the application of spectroscopy to spectrochemical analysis as this subject has not yet received the recognition in South Africa which it deserves.

The time at my disposal is comparatively short. My address will, therefore, necessarily be limited to a somewhat sketchy outline of the development of the method employed. I hope that those who are interested will find the bibliography cited useful to round off points in my address over which I have to pass rather superficially.

Part I—Historical Introduction.

In 1666 Newton discovered that if a narrow beam of sunlight coming through a small hole in a shutter of a darkened room was allowed to pass through a glass prism on to a screen, a strip varying in colour was observed. This was called a spectrum.

Fraunhofer in 1817 constructed the first instrument which could be called a spectroscope. He used a narrow vertical slit to limit the light falling on the prism, and the telescope of a theodolite to observe the sun's spectrum. He observed that the horizontal spectrum was crossed by a large number of vertical dark lines of varying degrees of darkness. He found that two of these lines, called D lines by him, coincided exactly with the two bright yellow lines produced in a flame in which ordinary salt evidently occurred as a contamination. Fraunhofer also

succeeded in measuring the wave-lengths of a large number of the dark lines in the sun's spectrum with an amazing degree of accuracy.

The work of Kirchhoff and Bunsen in 1859 and 1860 led to the firm establishment of spectrochemical analysis. Kirchhoff introduced ordinary salt, NaCl, into a Bunsen flame and observed that two bright yellow lines appeared in its spectrum. He allowed sunlight to fall through the flame into the spectroscope and found that the dark D lines of the sun's spectrum coincided with the observed bright yellow lines. He states:—

> "One can assume that the bright lines in the spectrum of the flame corresponding with the D lines of the solar spectrum originate from sodium. The presence of the dark lines D in the sun spectrum brings one to the conclusion, therefore, that sodium exists in the sun's atmosphere.
>
> "A way is therefore found to make a determination of the chemical constitution of the sun's atmosphere, and the same promises a future for chemical determination of the fixed stars." (Free translation by Twyman (1941: 28, 30).)

Kirchhoff and Bunsen were the first scientists who correlated observed lines with certain substances. They actually succeeded in discovering the elements rubidium and caesium in 1861 by means of their spectra.

Lockyer seems to have been the first in 1874 who suggested the possibility of making quantitative determinations by means of spectrochemical analysis.

The classical publication of Hartley in 1884 on the persistent lines of Mg, Zn, Cd, Al, In, Tl, Cu, Ag, Sn, Hg, Pb, Te, As, Sb and Bi was a definite step towards quantitative spectrochemical analysis. He indicated a correlation between element concentration and line intensity. This work was continued by Hartley and his collaborators. About 1907 Hartley, Pollok and Leonard used a solution system in which they indicated lines which were present in one concentration but absent in concentrations one-tenth that amount.

In 1920 De Gramont published his table of persistent lines or *raies ultimes*, which represented an important contribution to qualitative and quantitative spectrochemical analysis.

PART II—THEORY OF ATOMIC SPECTRA.

In the meantime the knowledge of the origin of atomic spectra had increased with great strides. As could be expected, this knowledge contributed to the further development of spectrochemical analysis. Hence I intend to give a short description of the most important points required in our further discussion.

With the advent of Bohr's theory of the hydrogen atom

in 1913 new life was infused into the study of atomic spectra. In 1885 Balmer had established that the wave-length λ of the well-known visible lines of the hydrogen spectrum could be represented by a simple formula:—

$$\frac{1}{\lambda} = \nu' = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right) \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where $n = 3, 4, 5$, etc., and where ν' is called the wave-number, and the constant $R = 109678{\cdot}72$ cm^{-1}.

In the succeeding decade Rydberg found that the wave-number of the spectrum line of any element could similarly be represented by the difference of two terms.

In 1911 Rutherford showed that his experiments on the scattering of α-particles could best be explained by assuming each atom to consist of a massive positively charged nucleus around which a number of negatively charged electrons revolved. The positive charge of the nucleus is equal to the total negative charge of the electrons, and nearly the whole mass of the atom was concentrated in the nucleus.

In 1900 Planck had shown that the energy distribution of black body radiation could not be explained by the classical theory which assumed that radiation was continuous. He had to assume that energy is emitted in discrete pulses or " quanta " of energy $h\nu$, where ν is the frequency of the pulse and h is a universal constant, known as Planck's constant.

Bohr (1913: 1, 476, 857) combined these two theories and Rydberg's discovery and laid down two postulates with the help of which he was able to obtain an atomic interpretation of Balmer's formula (1), viz.:—

$$\frac{1}{\lambda} = \nu' = \frac{2\pi^2 m e^4}{c h^3}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \quad (2)$$

where $n_1 = 2$ and $n_2 = 3, 4, 5$, etc., give the lines of the Balmer series of hydrogen, and

where m = the rest mass of the electron,
e = the electric charge of the electron,
c = the velocity of light in vacuo,
and h = Planck's constant.

Substituting the known values of these constants, Bohr obtained R in equation (1) = 109700 cm^{-1}, which was considered to be in close agreement with the empirical value of R given above. Further, $n_1 = 1$, and $n_2 = 2, 3, 4$, etc., gave the ultraviolet series of hydrogen which was discovered later by Lyman; $n_1 = 3$, and $n_2 = 4, 5, 6$, etc., gave the lines of the Paschen infrared series, and so on. There is no doubt, therefore, that at the time Bohr's theory was a great advance in the knowledge of atomic spectra.

Various discrepancies between Bohr's theory and experiment soon came te light as experimental evidence piled up. In 1924

De Broglie made the daring assumption that all matter in motion was accompanied by a wave of wave-length.

$$\lambda = \frac{h}{mv}$$

where h = Planck's constant,
m = mass of the particle,
and v = the velocity of the particle.

In the hands of Heisenberg and Schrodinger and others this assumption led to a new interpretation of atomic spectra, which included the results of Bohr's theory to a certain extent and gave further results which were completely in agreement with experiment.

The hydrogen atom with only one electron is the simplest to understand theoretically. As the number of electrons round the nucleus increases, the atom becomes more complicated, but the general arrangement of the electrons round the nucleus may be pictured as follows:—

When the elements are arranged according to increasing atomic weight, as in the periodic system, their position in the system is equal to their atomic number, with a few minor exceptions. The atomic number gives the number of unbalanced positive charges in the nucleus as well as the number of neutralising negative electrons arranged around the nucleus. These electrons are arranged in shells and sub-shells. The first shell is completed with two outer electrons in the atom helium. The second shell starts with one electron in the atom lithium and is completed with eight electrons added outside the first shell in the atom neon, and so on. Generally, each shell is completed when a stable noble gas atom is formed.

The spectrum of an element is now determined by the outer electrons—that is, the number of electrons outside a closed inner shell. In the case of the early elements of each period of the periodic system this number agrees with the chemical valency of the element.

By addition of energy one of the outer electrons is displaced from its normal energy level to a higher level which is unoccupied normally. The element becomes excited. As in the case of hydrogen, the electron, after a short sojourn in the excited state, returns to the lower, free energy level while certain definite rules are followed by it. The energy taken up by the atom during its excitation is now released as light of a definite colour or wave-length.

Fig. 1 gives an energy level diagram for sodium according to Grotrian (1928: 21). The lowest level corresponds to the normal state of the atom and the various higher horizontal lines to the possible excited states. In the left-hand margin the voltage differences between the normal state and the most

important levels of excitation are indicated, and at the top the terminology used to indicate the various levels or terms are given.

Further, it is possible that the excited states are not single but multiple. Thus in the case of sodium these excited states are double. The level which the excited electron chooses for its sojourn is determined by probability rules. In practice it is found that some atoms will be excited to state 1 and others to state 2. The electrons returning from this double state to the normal state will now radiate two lines instead of a single line. In the case of sodium we get the well-known double D_1 and D_2 lines which result from the transitions:—

$$2\ {}^2P_{\frac{3}{2}} \longrightarrow 1\ {}^2S_{\frac{1}{2}} \text{ giving } D_2 = 5889{\cdot}963 \times 10^{-8} \text{ cm.}$$

$$\text{and } 2\ {}^2P_{\frac{1}{2}} \longrightarrow 1\ {}^2S_{\frac{1}{2}} \text{ giving } D_1 = 5895{\cdot}930 \times 10^{-8} \text{ cm.}$$

From the diagram we see further that if energy greater than 5·12 volt is imparted to the sodium atom, the electron will be displaced above the boundary of the existing energy levels. The electron is actually removed out of the atom and the atom becomes ionised. A similar energy level diagram for the ionised atom can be determined. Transitions between these energy levels give the spectrum of the singly ionised atom. Similarly, spectra of doubly, trebly, etc. ionised atoms can be observed. In the case of iron the un-ionised atomic spectrum is denoted by Fe I. The singly, doubly, trebly, etc. ionised atomic spectra or Fe^+, Fe^{++} and Fe^{+++} spectra are indicated by Fe II, Fe III and Fe IV.

The following fundamental facts for spectrochemical analysis emerge from the theory of the structure of atomic spectra: Every element emits a characteristic spectrum when it is excited. The spectrum is determined solely by the configuration of the atom. The strongest lines of the spectrum will be those which correspond to transitions between the ground state and the first excited states above it with which it may combine. These are the characteristic or ground lines of the element, and they will always occur if an atom or its ion emits light. If the concentration of an element decreases, these lines will be the last to disappear. These are the lines known in spectrochemical analysis as the persistent lines or *raies ultimes* of De Gramont. If one looks for an element by means of its spectrum, it is not ncessary to search for all its lines, but it is sufficient to determine whether its ground lines are present in the spectrum. These ground lines can be deduced directly from the energy level diagram of the element. Thus the sodium D lines are the ground or persistent lines of sodium.

A further characteristic of these ground lines is that they very easily appear in absorption. Every atom can not only be

transferred from its ground state to an excited state by electron impact in an electrical discharge or by thermal energy, but also by absorbing radiation of a wave-length equal to that of the ground lines. Thus the sodium atoms in the sun's atmosphere absorb the wave-lengths from the sun's radiation which are equal to those of their ground lines and thus the Fraunhofer dark D lines result. For the same reason it will often be observed that in the spectrum of an energetic arc or spark in which excessive metallic vapour is formed the ground lines appear as white lines surrounded by a black haze in the photographic negative. These lines, we say, are reversed and are denoted by an R behind their wave-lengths in spectroscopy.

From the above it is clear that the relative intensities of the spectrum lines are determined by the processes taking place within the atom. It is also evident that in general the intensity of any single line of an element will be proportional to the amount of that element present in the light source. This fact is made use of in spectrochemical analysis.

Part III—Qualitative Analysis.

The application of spectroscopy to qualitative analysis dates back to the work of Kirchhoff and Bunsen in 1860. Their discovery that every element gives a characteristic spectrum led to the conclusion that an element would emit that spectrum under all conditions. Its spectrum could hence be used to identify the element even when it was not accessible as in the case of the sun and the stars.

The light source in which the atoms are excited may be an electric arc or spark between two conducting rods or between two carbon electrodes into one of which the unknown material is introduced. Most of the elements have persistent lines which lie in the ultraviolet, and hence it is usually necessary to obtain a spectrogram of the light source by means of an ultraviolet spectrograph. The medium quartz spectrograph and the large Littrow type quartz and glass spectrograph of Messrs. Adam Hilger of London are the best known in South Africa, but the grating spectrograph of Messrs. Dietert of Detroit is being used very extensively in the U.S.A.

After obtaining a spectrogram of the unknown material the spectrum of a known element or compound should be photographed alongside the unknown by means of a Hartmann diaphragm. The known substance may be of iron, copper, a *raies ultimes* compound or a sample of the main constituent of the unknown. Usually the instrument has a printable scale which can be recorded on the other side of the unknown spectrum.

The procedure of qualitative analysis may be divided into two parts—(a) the search for a definite element, and (b) the identification of unknown elements.

In the search for a definite element it should be sufficient to determine whether the persistent lines of the element are present in the unknown spectrum. Very often this can be accomplished by means of the scale printed alongside the spectrum on which the wave-lengths can be estimated visually to within 1 or 2 A units, where one Angstrom or A unit $= 10^{-8}$cm. To make quite sure, a spectrum of the element looked for can be photographed alongside the unknown spectrum with the aid of the Hartmann diaphragm. It is a very simple matter now to determine whether the strongest lines in the known and unknown spectra correspond.

The identification of unknown elements requires a more accurate identification of the spectrum lines. In this case the identification of the unknown lines is greatly facilitated if spectra of all the constituent elements are at hand in the laboratory. These spectra should preferably have been procured with the same spectrograph. The known and unknown spectra may now be projected alongside one another by means of a special spectrum viewer apparatus and thus all the lines may be identified. In this way the elements present in the unknown sample may be determined.

If all the spectrum lines cannot be identified in this way, it becomes necessary to compute the wave-lengths of the unknown lines as accurately as possible. This can be carried out by measuring the separation of the lines on the photographic plate by means of a travelling microscope or comparator accurately to a thousandth mm. and by interpolating between three spectrum lines of known wave-lengths with the aid of Hartmann's formula:—

$$\lambda = \lambda_0 + \frac{B}{q - q_0} \qquad \qquad (3)$$

where λ represents the wave-length of the unknown line and q the corresponding reading of the comparator. λ_0, q_0 and B are constants which can be procured from three readings of the comparator q_1, q_2 and q_3 for three known wave-lengths λ_1, λ_2 and λ_3. The wave-lengths thus determined can be compared with those given in one of the standard wave-length tables (Harrison, 1939, and Kayser-Ritschl, 1939).

The value of qualitative spectrum analysis in mineralogy may be illustrated by the following example: Research conducted on the nickeliferous ores of East Griqualand led to the discovery of a rare mineral species termed parkerite by Prof. D. L. Scholtz (1936: 81) of the Geology Department of the University of Stellenbosch. Michener and Peacock (1943: 343) succeeded in separating a small quantity of an apparently similar mineral from concentrates obtained from Canadian nickel ores. The subsequent detailed chemical, optical and X-ray investigation of this material led them to conclude that it was

identical with parkerite except for the presence of the element Bi not previously recorded in the case of the South African mineral.

Owing to the fact that a single polished ore specimen constituted the only available source of more South African parkerite, Prof. Scholtz concluded that a spectrographic analysis provided the only possible method of tackling the problem. Two specially treated graphite electrodes were accordingly charged with a small fraction of a milligram of uncontaminated parkerite, one sample recovered by means of a microdrill and the other by the microscopical hand-picking of a concentrate obtained from part of the specimen, and were submitted to Dr. A. Strasheim of our Physics Department for spectrochemical analysis.

The spectra of these two samples proved to be identical. In Fig. 2 the spectra of iron, nickel, bismuth, parkerite (a), parkerite (b) and Pb are reproduced. The analysis lines of lead as well as those of nickel and bismuth are present in the spectra of the two parkerite samples. From the above it is clear that the element lead is an important constituent of parkerite. The fact that the spectrographic analysis of the Canadian mineral conducted by Michener and Peacock did not reveal the presence of this element is significant, and the question now again arises whether the two minerals are really identical.

Part IV—Quantitative Analysis.

(a) *Gerlach's Fundamental Work.*

Meggers, Kiess and Stimson (1922) published a number of quantitative spectrographic determinations on samples containing Cu, Pb, Fe, Zn, Ni, Ag and Bi, using the methods proposed by De Gramont in 1895. Their work marks the beginning of photographic registration of spectra for quantitative spectrochemical analysis. By a comparison of the results obtained by spectrographic and chemical analysis they showed that this new method could give quantitative results of considerable accuracy. The unknown sample was sparked in a condensed spark and the spectrogram obtained was compared with spectrograms obtained under similar sparking conditions from the known standards. The intensity of the persistent lines of the unknown and known samples were compared visually. In this way the concentration for which the known and unknown samples produced lines of equal intensity could be determined and hence the concentration of the element in question in the unknown sample could be estimated.

Modern spectrochemical analysis, however, is to a great extent based on the fundamental work done by Gerlach and his collaborators in 1927 and the following years (Gerlach and Schweitzer, 1930, Gerlach and Gerlach, 1933, and Gerlach and Riedl, 1936).

Gerlach's experimental work led him to the conclusion that the persistent lines or *raies ultimes* of De Gramont were lines which had the greatest intensity under the chosen conditions of discharge and photography. He further concluded that owing to the variation of the excitation voltage from element to element any spectrochemical method giving good results for the percentage abundancy of one element compared with another held only for that case. Any spectrochemical determination of a new element, therefore, required a standardisation of the method of analysis for this element.

He pointed out that the accuracy of any determination depended on the following criteria—the type of discharge used as light source, the spectrograph, the kind of photographic plate used, the developing technique, the accuracy of the photometer work (if any), and on whether the lines studied were single. He stipulated that the wave-length regions in which the prism and the lenses of the spectrograph absorbed or the metallic gratings reflected poorly should be avoided, and that the wave-length region 2300—2400 A should be avoided owing to the absorption of the light by the gelatine of the plate. He concluded that very important spectrochemical analyses could be carried out much faster than by chemical means provided that all the necessary precautions were taken.

In his early work Gerlach used a method very similar to that followed by Meggers and his collaborators. Thus in a case where a sample such as a copper rod was to be analysed which contained a large percentage copper or primary substance P and a small unknown percentage x of an impurity element Z, Gerlach proceeded as follows: Several standard samples of P containing known percentages a, b, c, etc. of Z were prepared. Spectra from these standard samples and from the unknown sample were procured under the same conditions. By visual estimation he was able to determine which standard sample gave a spectrum in which any chosen line had the same intensity as the same line in the spectrum of the unknown sample. From this he was able to infer the percentage of Z in the sample under investigation.

Gerlach soon developed two fundamental methods, the first of which is known as the internal standard method. He observed that in the spectrum of a primary substance P containing x per cent. of an additional element Z it was possible to find adjacent lines of P and Z which had equal intensities in the standard mixture. It was a very simple matter to determine whether these lines had equal intensities in any unknown sample. If this was the case, the unknown sample contained the same relative amounts of P and Z.

In this connection he made a very important observation, viz., that the relative intensity of these two lines of P and Z

depended to a great extent on the conditions of excitation He therefore prescribed that an extensive variation of the conditions of excitation should be carried out before two such lines were chosen for spectrochemical analysis. If their relative intensities remained the same over a large range of varied conditions of excitation, they could be chosen for the analysis, and they were then called a " homologous pair of lines." In addition, he prescribed that another line pair, usually an arc and a spark line of the substance P, should be chosen which had equal intensities in about the middle of the above range of variation of excitation conditions, but whose intensities varied strongly as soon as these conditions were departed from. These two lines were called the " fixation pair " by him. They could be used as a sensitive control of the excitation conditions.

He stated that for an exact determination of homologous and fixation pairs one could revert to the spectral analysis of the individual elements. Homologous lines would be those lines of P and Z which require approximately equal energies for their excitation, and fixation lines would be those lines of P which differ greatly in the energies required for their excitation.

The second method developed by Gerlach is known as the substitution method. He found that very often it was impossible to find a homologous pair of P and Z which lie close together on the photographic plate and which made a visual comparison of the intensities of the line pair possible. To overcome this difficulty he photographed an auxiliary spectrum of an element A on top of that produced by P and Z. The exposure time was varied until a homologous pair of equal intensity was found for Z and A which lie close together on the plate. It very often happened that in another part of the plate a homologous pair of A and P occurred which had equal intensities and fell in close proximity on the plate. With the aid of the superposed spectrum of the auxiliary element A, therefore, it was possible to determine by visual comparison whether the percentage Z in the unknown sample agreed with the standard mixture of P and Z.

These methods were employed by Gerlach and his collaborators to determine whether standard solutions conformed to specifications, to determine Pb in blood and As in various parts of a body in a case of poisoning, etc.

Spectrochemical analysis, however, is not limited to the determination of definite concentrations by the method of equal intensities of a homologous line pair. If a homologous pair of lines of the two elements P and Z has a definite intensity ratio at a certain concentration ratio and under definitely controlled excitation conditions, it is possible to determine any unknown concentration of Z if we are able to estimate the intensity ratio of the pair of lines accurately.

(b) *The Photographic Plate and its Calibration.*

Line intensity may be determined in a number of ways, nearly all of which are photographic in character. Hence we intend to discuss briefly the theory underlying the formation of an image or a spectrum line on a photographic plate.

It is well known that for neighbouring areas of a photographic plate and for constant time of exposure the density of blackening d of the developed plate is related to the logarithm of the intensity I of the light causing the blackening in the way represented in Fig. 3. This curve is called an H and D curve after Hurter and Driffield (1890: 455). The curve shows that d is a linear function of $\log_{10} I$ for a considerable range *ab* of the curve. This linear portion of the curve may be represented by the general formula:—

$$d = \gamma \log_{10} I \cdot t^{p} - \delta \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where t = time of exposure and is kept constant here, and where γ, p and δ are approximately constant. $\gamma = \tan \theta$ represents the gradient of the straight portion of the curve.

The density of blackening d can be determined by means of the microphotometer or densitometer, as it is called in the U.S.A. In principle, the microphotometer consists of a steady light source, such as an incandescent projection bulb connected to a battery of large capacity or some kind of voltage regulator, the focusing of the light on the plate to be measured in the form of a line by means of a slit in front of the light source, and finally the illumination of a light sensitive cell with the beam passing through the plate. The photronic cell which can be connected directly to a sensitive aperiodic galvanometer is preferred mostly to the photocell and the thermopile owing to the simplicity of the electrical circuit and the constancy of the cell. The density of the line is here measured in terms of the galvanometer deflection read on a scale. It is wise, however, to test the linear response of the cell from time to time by measuring a standard density wedge with the microphotometer. The wedge consists of a number of adjacent platinum layers of different known thicknesses sputtered on a quartz plate.

If i_0 represents the intensity of the light beam of the photometer bulb passing through a clear portion of the plate, and D_0, the corresponding deflection of the galvanometer; and if i represents the intensity of the light beam passing through the spectrum light on the plate, and D the corresponding deflection of the galvanometer, the density of blackening d of a spectrum line may be defined by:—

$$d = \log_{10} \frac{i_0}{i} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

But owing to the linear response of the photronic cell $i_0 = k\,D_0$ and $i = k\,D$ where k is a constant.

Hence
$$d = \log_{10} \frac{D_0}{D} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

From this equation it is therefore possible to determine d in equation (4) and thus the ordinate of the curve in Fig. 3.

In order to determine the abscissa $\log_{10}I$ in Fig. 3, we have to vary I in a known way. Owing to the failure of the reciprocity law that I.t = constant, it is safest to keep t in equation (4) constant and to vary I itself in a known way. Several methods have been used, such as

(1) increasing the distance between a point source and the plate and assuming the intensity of the light to decrease proportionally to the square of the distance;
(2) the stepped sector method of Scheibe (1929: 1017);
(3) the stepped weakener method of Von Angerer (1931: 145); and
(4) the stepped slit method of Thomson and Duffendack (1933: 103).

Although method (1) is probably the most accurate, it is difficult to adopt in a laboratory owing to limited space.

Thomson and Duffendack have shown that the stepped slit method gives equally good results. Since this method can be used in any laboratory, and is used extensively to-day, only the stepped slit method will be described in greater detail here.

The stepped slit method of calibrating a photographic plate was first proposed by Hansen (1924: 356) and was applied to spectrochemical analysis with certain modifications by Thomson and Duffendack. The stepped slit required can be constructed in the laboratory. Several strips of tin foil with square ends are pasted with increasing slit width over the slot of a frame which fits exactly in the grooves of the slit mechanism of the spectrograph. By means of a travelling microscope the widths of the various slits comprising the stepped slit can be made as desired while pasting the strips on the frame. Usually a stepped slit consists of about six slits with different widths all arranged about a common centre line. Thomson and Duffendack made the width of their widest slit about 3 mms. Each step was chosen about 1·5 times as wide as the next smaller one.

This stepped slit is now substituted for the actual slit of the spectrograph, which is completely removed or set wide open. The slit is then illuminated by a light source giving a continuous spectrum such as the hydrogen arc of Allen and Franklin (1939: 453). To facilitate the setting up, a small source is chosen which is set sufficiently far away so that the slit is evenly illuminated and so that all the light passing through the stepped slit also passes through the collimator lens. The continuous spectrum of hydrogen extends over the whole range of wavelengths in which measurements of intensity can be made with ordinary plates. It is therefore very suitable for calibrating plates for measurement of intensities in the ultraviolet.

The intensity of the light, I, passing through the various slits of the stepped slit, will now be proportional to the slit widths provided that the slits are not too narrow nor too wide. The corresponding values of the density of blackening, d, produced on the photographic plate can now be determined by means of the microphotometer as described above. Care must be taken that the density of blackening of the plate is measured in the region of the plate in which the analysis lines of the element in question lie, for the slope or gamma of the H and D curve of certain photographic plates changes with the wavelength region. The H and D curve giving d plotted against the log relative intensities can then be constructed. The plate is now calibrated for quantitative work.

This method of plate calibration has two important disadvantages:—

(1) The spectrum of the light passing through the stepped slit must be photographed on every plate, and this spectrum occupies a large amount of valuable space on the plate; and

(2) A suitable continuous light source is not available in every laboratory.

This method has, therefore, recently been superseded to some extent by a method which makes use of the relative intensities of the lines belonging to a spectrum which is rich in lines, such as the spectrum of the iron arc. By studying the atomic energy level diagram of the iron spectrum, Dieke and Crosswhite (1943: 427) showed that certain lines of the iron spectrum have constant $\log_{10}I$ values even under widely different conditions of excitation. The $\log_{10}I$ values of a number of iron spectrum lines were determined in the region 3140—3240 A on a plate calibrated by one of the above standard methods by Dieke and Crosswhite. They expressed their intention of making similar determinations for other regions of the iron spectrum. As soon as these determinations are published by them, it will be possible to calibrate the photographic plate by this new method, provided a steady iron arc giving reproducible results such as that of Slavin (1940: 131) is employed.

If the iron arc spectrum is photographed on every plate which is to be calibrated, the H and D curve can be constructed by measuring the d values of the lines whose relative $\log_{10}I$ values are known according to determinations such as those of Dieke and Crosswhite. By this method it is possible to calibrate a plate with much less loss of plate space and with means present in every spectrochemical laboratory. The method is especially useful in cases where iron and steel analyses are to be made. In such cases the iron spectrum is necessarily present and no extra spectrum is needed for plate calibration.

(c) *The Construction of the Working Curve.*

The next step is to construct a working curve for the determination of an unknown element. Suppose, again, that an element, Z, present in the primary substance P must be determined. The first step necessary is to find a homologous pair of lines representing P and Z. About eight specimens containing various known amounts of Z and the same amount of P are prepared. Triplicate spectra corresponding to each specimen are taken to average out any variation due to sampling errors, light source fluctuations or microphotometer determinations. All the spectra are taken under the same conditions of excitation, which are rigidly controlled. The plate holder is moved just sufficiently between exposures to obtain 24 adjacent spectra corresponding to the eight specimens. The stepped slit or iron arc calibration spectrum is photographed below these 24 spectra. Since photographic plates deteriorate from the edges inwards when they grow old, it is often found advisable to photograph the calibration spectrum in the middle of the plate. In this case 12 of the specimen spectra can be photographed on either side of it.

The H and D curve for the region in which the homologous line pair of P and Z lie is determined from the calibration spectrum by means of the microphotometer as described above.

The working curve can now be constructed as follows: The d values for the P and Z line pair is determined for each of the 24 spectra. From the H and D curve previously determined the d values corresponding to the P and Z lines can now be converted to $\log_{10} I_p$ and $\log_{10} I_z$ (see Fig. 4). Care must be taken to make sure that the exposures are so regulated that the conversion of d to $\log_{10} I$ values can be read from the straight portion of the curve:—

$$\log_{10} I_Z - \log_{10} I_P = \log_{10} \frac{I_Z}{I_P}$$

gives us the log relative intensity of the Z and P lines.
But $I_z \propto Z$, the concentration of Z in the specimen,
and $I_p \propto P$, the concentration of P in the specimen.

Hence $$\log_{10} \frac{I}{I_P} = \log_{10} \frac{Z}{P} \quad . \quad . \quad . \quad . \quad (7)$$

$\log_{10} \dfrac{I_Z}{I_P}$, as determined from the H and D curve, is now averaged for the eight specimens and is plotted against the log known percentage of Z present in every specimen. In practice this will usually give a straight line curve in agreement with equation (7) as illustrated in Fig. 5. This graph constitutes a working curve which can now be used to determine any unknown percentage of Z in the primary substance P.

If any specimen containing P and an unknown percentage of Z is to be analysed, its spectrum is taken in triplicate together

with the triplicate spectra of one or more of the known specimens and a calibration spectrum is photographed on the same plate. The spectra of the known specimens serve as a check on the working curve, but need not be photographed on every plate as soon as the working conditions are sufficiently standardised. The d_p and d_z values of the unknown specimen are determined by means of the microphotometer, the corresponding $\log_{10} \frac{I_Z}{I_P}$ can be obtained from the H and D curve and the log percentage Z is then read off the working curve.

The logarithmic sector method introduced in spectrochemical analysis by Scheibe (1929: 1017) has also been used to determine line intensities and hence for quantitative analysis. Owing to lack of time it is impossible to discuss this method here. Twyman and Simeon (1929: 169) give a full account of the underlying theory, and Brode (1941: 83) gives an account of its application to spectrochemical analysis. This method has to a great extent been superseded by the microphotometer method described above.

Part V—Light Sources and their Characteristics.

So far very little has been said about the various methods of excitation of spectra. The following comparison of the three most important light sources may prove to be useful to prospective workers in this field.

(a) *The Direct Current Arc.*

The discussion of the D.C. arc includes the cathode layer excitation of the direct current arc. The wiring diagram is indicated in Fig. 6.

The D.C. arc is maintained between two electrodes of an electrically conducting solid sample or between two carbon or metallic electrodes in the cavity of one of which a small amount of the powder or liquid specimen is placed. The voltage supply used varies from 250 to 90 volts and the current employed from 1 to 20 amperes. The current is usually drawn from a storage battery of large capacity or from a generator set. It is important that there should be no fluctuations or change of the voltage applied during exposures.

The characteristics of the D.C. arc are as follows:—

(1) Its concentrational sensitivity is high. 0·001 to 0·0001 per cent. of a metallic element is determinable by means of the D.C. arc, and 0·0001 to 0·00001 per cent. by means of the cathode layer of the D.C. carbon arc respectively;

(2) Quantitative analytical results obtained by it vary erratically and suffer from poor reproducibility;

(3) The arc usually gives an intense background, especially in the region 3200—4000 A, which is very objectionable in microphotometer work;

(4) The intense heat generated in the arc is unpleasant;

(5) The arc is very corrosive on carbon electrodes;

(6) Owing to the high temperature of the arc, deep-seated impurities in the electrodes distill into the arc and cause the so-called latent impurity difficulty;

(7) The specimen is very often oxidised while the exposure is in progress;

(8) At the high temperature of the arc, the relatively different volatilisation rates of the different elements in a sample cause difficulties;

(9) The line intensity is not uniform along the length of the arc;

(10) In the case of the cathode layer arc an optical system is required for accurately focusing a restricted portion of the arc upon the slit of the spectrograph; and

(11) The accuracy of the quantitative determinations with the D.C. arc is about 10 per cent.

The D.C. arc is specially suited for the analysis of (i) Metallurgical specimens as shown by Ritchie (1929: 1); (ii) organic compounds and biological materials as demonstrated by Cholak and Story (1941:730); and non-conducting solids such as minerals, sands, etc. (Ahrens, thesis 1944).

(b) *The Alternating Current Arc.*

The electrical connections of the A.C. arc are given in Fig. 7. Arc currents of 1 to 6 amperes are ordinarily used at potentials of 1100 or 2200 volts. The arc may be maintained between two solid electrodes of the sample or between two graphite or metallic electrodes upon each of which a drop of the test solution has been dried previously.

The characteristics of the A.C. arc are as follows:—

(1) It has a high concentrational sensitivity. In general the sensitivity of detection of any metallic constituent of a chemical material is of the order of magnitude of 0·0001 per cent. in the A.C. arc;

(2) The sensitivity of detection of phosphorus is from five to ten times that obtainable by the D.C. arc or cathode layer of the D.C. arc;

(3) The weak background is a great advantage;

(4) The line intensity is uniform throughout the entire arc length ordinarily employed;

(5) No special optical system is necessary for focusing the arc on the slit;

(6) The A.C. arc is very easy to maintain;

(7) The A.C. arc is very economical on electrode material;

(8) When used as light source the A.C. arc gives a fair reproduction of quantitative analytical results;

(9) The accuracy obtainable varies from 5 to 10 per cent.; and

(10) According to Strasheim (thesis 1943) the following elements could be determined in biological material in the same test solution by the A.C. arc method and in the concentration ranges given:—

Mn, Cu, B, Fe, Al and Ni ...	0·0001% to 0·02%
Ca and Mg	0·0001% to 0·2 %
K	0·02 % to 4 %
P	0·01 % to 4 %

The A.C. arc is suited for the analysis of: (i) Metallic samples as shown by Nusbaum and Hackett (1941: 620); and (ii) organic and biological salts as demonstrated by Hess, Owens and Reinhardt (1940: 33) and by Strasheim (1943: 110) respectively.

The graphite or carbon electrodes used extensively in connection with the A.C. arc method of excitation can be purified by the method of Staud and Ruehle (1938: 59) or by the slightly modified method of Strasheim (1943: 24).

(c) *The High Voltage A.C. Spark of Feussner (1932 573).*

The wiring diagram given in Fig. 8 is according to Sawyer and Vincent (1938: 2).

The characteristics of the high voltage A.C. spark are:—

(1) The concentrational sensitivity is low;

(2) It gives a large concentrational working range, viz., 0·01 per cent. to 5 per cent.;

(3) The accuracy attainable is approximately 1·2 per cent.; and

(4) It is not adaptable to non-metallic solid analysis.

The high voltage A.C. spark is suited for the analysis of: (i) Metallic bar samples such as cast iron and steel samples. It has become the most important method of excitation for steel analyses in the steel industry and the spectrochemical quantitative analysis of steel samples has largely replaced the older chemical methods; and (ii) solutions as shown by Hitchen and Twyman (1931: 72).

Part VI—Further Applications of Spectrochemical Analysis in Science and Industry.

It is almost impossible to give a complete summary of all the applications of spectrochemical analysis, for new adaptations of the method are evolved almost daily.

In agricultural laboratories it is used to investigate the influence of traces of minerals on the reproductivity of plants and their freedom from diseases. By means of the spectrograph it has been discovered by O'Connor (1941: 597) that a slight

deficiency of zinc in soil makes a great difference in the yield of citrus fruits, apples and grapes.

Ferrous analysis has been advanced to the stage that the complete composition of cast iron and steel, as well as alloys in ordinary concentrations (except carbon, phosphorus and sulphur), can be determined in less than fifteen minutes.

Ores and scrap metals can be assayed within half an hour for all the seventy elements that the spectrograph is able to detect. Owing to the saving of time, such an assay costs a fraction of the older procedure of wet analysis.

Costly and rare metals can be examined for impurities by the spectrochemical method, the advantage of this method being that only a very small sample is needed and practically nothing is consumed during the determination.

Spectrochemical analysis has further been applied with success in hospitals for the analysis of blood, various secretions, gallstones, etc. Thus Sawyer, Waggoner and Ericson (1940: 47) determined lead in human blood by this method.

In criminological laboratories this method has been used to corroborate evidence found by other means. Thus according to Walker (1939: 3) a remarkable accident took place near Boston, U.S.A., in which a man was killed and fourteen different motor cars were involved, but none of the fourteen drivers of the cars admitted striking the man. Upon examination of the clothing of the man a small particle of paint was found to be impressed in the fabric near a tear in his overcoat. This paint was compared microscopically and spectrographically with the paint on the fourteen cars. It was found that the paint on only one of the cars agreed perfectly with that found on the overcoat. Thus it was possible to conclude that the car with the corresponding paint had struck the man.

Other fields in which spectrochemical analysis has been applied with success are: Ceramic, glass and food industries, all phases of metallurgy, dentistry, organic and inorganic chemistry and biology. Thus in the field of inorganic chemistry certain elements such as Zn and Te can only be analysed with great difficulty by chemical methods, but can be determined with ease and great economy of time by the spectrochemical method.

As regards the accuracy of spectrochemical methods, it may be stated that generally the chemical methods are more accurate where the element to be determined comprises more than 5 per cent. of the specimen to be analysed. Between 1 and 5 per cent. the chemical and spectrochemical methods give comparable quantitative results. Under 1 per cent. the spectrochemical method has generally been found to be superior to the chemical methods of analysis.

In conclusion it may be stated that, although the initial cost of the necessary apparatus is high, experience has already

proved that most modern industries in America and Europe find the spectrochemical method of analysis more economical than the chemical method owing to the great saving of time.

It is hoped that the above discussion will bring this method to the attention of scientists and industrialists in South Africa, and that it will help prospective workers in this field to obtain a clear insight into the method and its possibilities.

Summary.

The early history of spectrochemical analysis is briefly sketched. The most essential features of the theory of atomic spectra are discussed. Important points in connection with qualitative spectrochemical analysis are summarised and an illustrative application is described.

The development of the methods of modern quantitative spectrochemical analysis is discussed in greater detail in order to give a clear exposition of a method suited to South African conditions. This discussion includes a description of the fundamental contributions of Gerlach, the characteristics and the calibration of a photographic plate, the determination of spectrographic line intensities by means of the microphotometer, and the construction of a working curve from which the amount of the unknown element can be deduced.

A summary is given of the most important light sources, their characteristics, and the types of analyses for which they are most suited.

In conclusion the applications of spectrochemical analysis not yet mentioned are briefly discussed.

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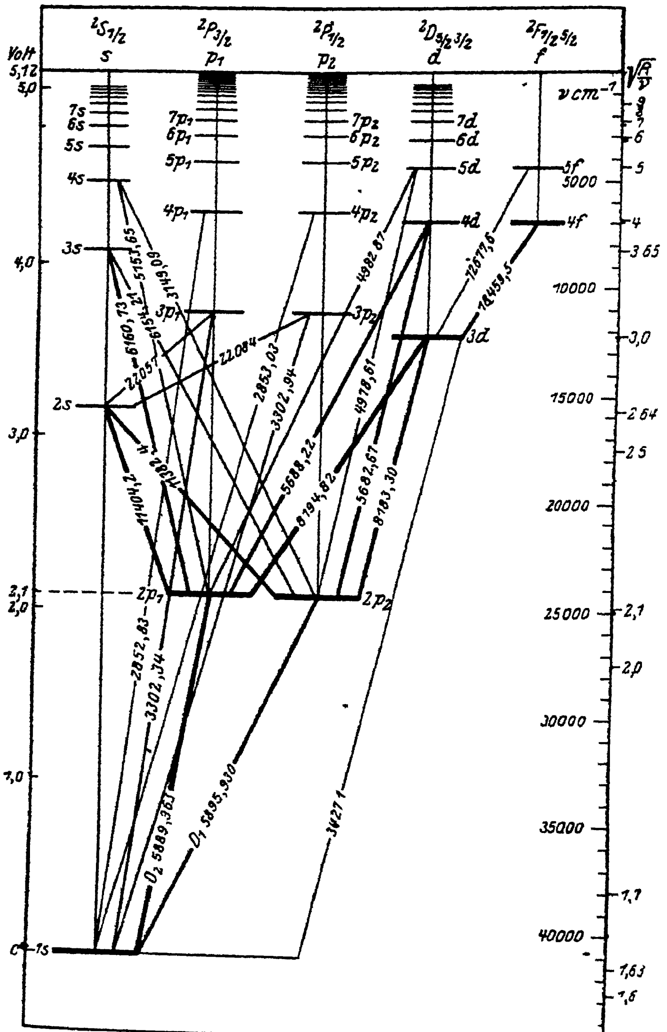


Fig.1. Energy level diagram of Sodium I.

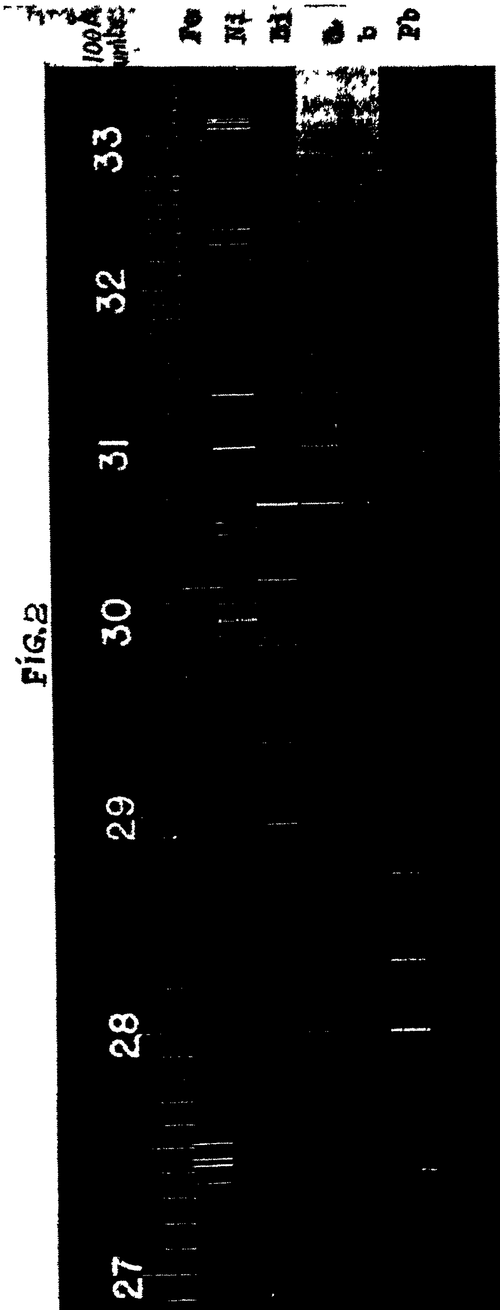
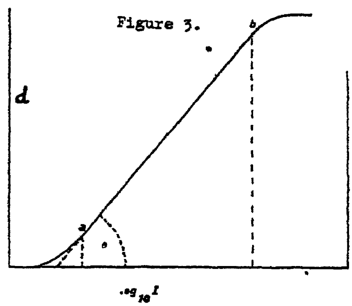
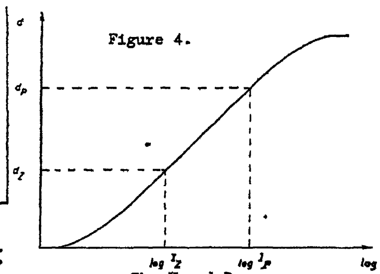


FIG.2

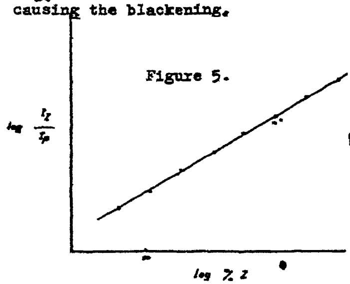
[illegible] - Spectra of Peckerite minerals.



H and D curve of photographic plate. Variation of the density of blackening d of a photographic plate with $\log_{10}$ of the intensity I of the light causing the blackening.



The H and D curve.



The working curve.

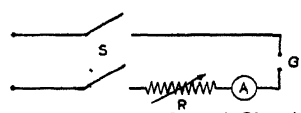


Figure 6. The Direct Current Circuit.

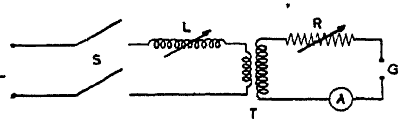


Figure 7. The Alternating Current Circuit.

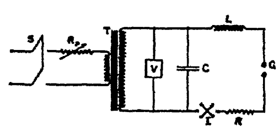


Figure 8. The Condensed Spark Circuit

A = ammeter, A.C. ammeter; C = condenser; G = arc gap, spark gap; I = synchronous interrupter; L = inductance; variable inductance; R = resistor, adjustable resistance; R_p = adjustable resistance; S = line switch; T = step up transformer, high voltage transformer; V = electrostatic voltmeter.

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DESIGNING THE METALLURGICAL PLANT FOR A WITWATERSRAND GOLD MINE.

BY

T. K. Prentice,

Central Mining and Investment Corporation, Ltd.

With 1 Text Figure.

Presidential Address to Section B, read 4th July, 1944.

Before proceeding with the subject of my address, I wish to take this opportunity of thanking the Association for the much appreciated honour it has conferred upon me in electing me President of Section " B " for the current year. This Section covers the field of Chemistry, Geology, Metallurgy, Mineralogy, and Geography and it is therefore not easy to choose a subject for an address which would be of general interest to all members and at the same time within the scope of the author. In these circumstances, I have decided to deal with Witwatersrand gold metallurgy, with which I have been closely associated for over a third of a century. In doing so, I propose to make a brief reference to the probable early history of a new Witwatersrand Gold Mining Company and then to describe how the Consulting Metallurgist would set about the task of designing the flow-sheet and the Metallurgical plant for the new Company.

The gold ores of the Witwatersrand exist as relatively narrow tabular sheets of conglomerate, locally known as " reefs," which vary from many feet in thickness down to a single layer of small pebbles. These reefs are separated from each other by inter-bedded sheets of quartzites or shale, which are normally free of gold and which form part of the Witwatersrand system of conformable sediments. The dips of the reefs vary considerably but average about 30° from the surface down to undetermined depths exceeding 10,000 feet. The reefs themselves are made up of closely packed rounded gold-free quartz pebbles mostly about grape size, set in a quartzite matrix, which carries pyrite, gold, silver, osmiridium and, on rare occasions, diamonds. The gold occurs in the metallic state in the approximate proportion of ten of gold to one of silver, the grains being usually very irregular in shape and in an exceedingly finely divided form.

Owing to the nature and the depth of the Witwatersrand gold deposits now being exploited, it is necessary to spend several million pounds to bring a Witwatersrand gold mine to the producing stage and each mine, therefore, must be large enough to give promise of an output of gold sufficient to justify such

capital outlay. Thus the average mining area per mine in 1943 for the forty-seven producing mines on the Witwatersrand, from Nigel to Klerksdorp, was 3,050 claims, equivalent to 7·0 square miles.

The majority of the mines on the Witwatersrand are, due to considerable shareholdings therein, under the control of one or other of several large financial corporations, which maintain, at their head-offices in Johannesburg, expert geological, mining, mechanical, metallurgical and secretarial staffs, whose services are available to the individual mines of their particular " Group." Thus the advice of experts is available to any one mine and, in this way, efficiency of a high order is maintained. Moreover, the fact that gold mining is not a competitive industry permits the general interchange of information between the various Groups and it is a very creditable fact that the latest developments in mining, metallurgical and engineering practice in any one Group are readily made known to the others. Incidentally, one very important avenue through which mining technical information is disseminated is through the publications of the many excellent scientific societies existing in South Africa.

Prior to a decision to form a mining Company, the interested Group would investigate the prospects of the contemplated venture and in this matter the Consulting Mining Engineer would be guided by his knowledge of the Witwatersrand system as a whole, by the available data pertaining to the neighbouring mines, and by the advice of his Consulting Geologist.

Should the outlook appear attractive, the Group, if not itself the owner of the mineral rights, would endeavour to obtain an option to purchase these rights from the mineral owner. This option would include the right to prospect the area and, provided the option is obtained, the prospecting work would be carried out under the direction of the Consulting Mining Engineer who might call for a geophysical survey, explore the reef by driving from an adjoining property or sink bore holes. If the reef is present at a shallow depth the prospecting work would probably also include some shaft sinking and development. As, however, in most cases the reef will lie at a considerable depth, the work of shaft sinking would usually be left until after the Company has been formed.

Should the results of this preliminary prospecting prove favourable, the Group, if not already the owner, would exercise its option to acquire the mineral rights and thereafter would apply to the Mining Leases Board for a mining lease.

According to the Gold Law of this country, the owner of the mineral rights of a farm is entitled to the exclusive right to mine precious metals on only one-quarter of the mineralized portion of his farm as determined by the Government Mining Engineer. For this purpose, however, the owner may select, subject to the approval of the Minister, any integral quarter and

this is known as his mynpacht. The mineral rights of the remainder are taken over by the Government to be disposed of as it wishes. Owing to the fact that one-quarter of the mineralized portion of the farm is likely to be inadequate for a modern gold mine, the Government is prepared to lease to the owner of the mynpacht sufficient of the adjoining ground under its control to meet the requirements of a large mine, on condition that the proposed Mining Company will pay to the Government a percentage of its nett profits, after allowing for capital redemption, on a sliding scale determined by the Mining Leases Board. This participation in the profits is the direct result of joint ownership of the mining title and should not be confused with the taxation to which all mines are subjected whether operating on a lease basis or not. In granting a mining lease, the Mining Leases Board may so adjust the lease formula that due allowance is made for the owner's mining rights, in which case the mynpacht need not necessarily be defined.

In some cases there may remain sufficient area under Government control to justify the formation of another Mining Company. In such an event, the Government would call publicly for tenders for the right to undermine a defined area on a similar basis of a percentage of the nett profits, after allowing for capital redemption, and the Mining Leases Board would advise the Government which tender to accept, after which, a lease agreement would be entered into.

The mining title having been acquired, the Consulting Mining Engineer would obtain from the Consulting Metallurgist an opinion as to the plant required to give a reasonable percentage of gold extraction from the ore, and from the Consulting Electrical and Mechanical Engineers estimates of the cost of obtaining a power supply and the cost of the necessary machinery, plant and buildings. Housing requirements for Europeans and natives would also be taken into consideration and steps would be taken, if necessary, to acquire the freehold of sufficient surrounding land to meet the proposed Company's requirements. Thus a complete estimate, necessarily only approximate, of all costs, including shaft sinking and development, would be obtained.

On the basis of this estimated capital expenditure and assuming that the prospects are sufficiently favourable, the financial advisers of the Group would decide upon the amount of capital required by the proposed new Company to operate the area and a prospectus would be issued accordingly.

The Company having been formed, the Consulting Engineer would pay considerable attention to the location of the shafts and all surface equipment which is likely to be required during the life of the mine and would make due allowance for ground on which to store residues, etc. Thereafter shaft sinking would be commenced.

When the shaft or shafts reach the reef, samples would be immediately taken for assay purposes and for practical metallurgical investigation and in formulating the procedure for the latter and in deciding finally upon the flow-sheet of the proposed reduction plant, the Consulting Metallurgist would obviously be guided by the past history of Witwatersrand metallurgical practice and by the results being obtained by producing mines at the time of the investigation. In view of the large capital outlay required for a modern reduction plant he would, of course, hesitate to make any radical departure from proved up-to-date practice unless there were very strong reasons therefor.

The past history of Witwatersrand metallurgical practice dates back to 1886, fifty-eight years ago, when the ore body was discovered.

From 1886 to 1890, the metallurgical flow-sheet was extremely simple and consisted of passing the total ore from the mine over a grizzley at the shaft head to permit breaking the oversize in jaw or gyratory crushers and passing the whole through a stamp mill using 30 linear mesh screening. The product from the stamps flowed over copper plates coated with mercury and about 75 per cent. of the gold was caught thereon in the form of a pasty amalgam, which was periodically scraped off and cleaned and the gold bullion was recovered by retorting the clean amalgam. When the mines entered the sulphidic zone, the gold recovery dropped to less than 60 per cent. but this was improved to about 74 per cent. by the use of blankets and frue vanners, from which the concentrate was subjected to a chlorination process.

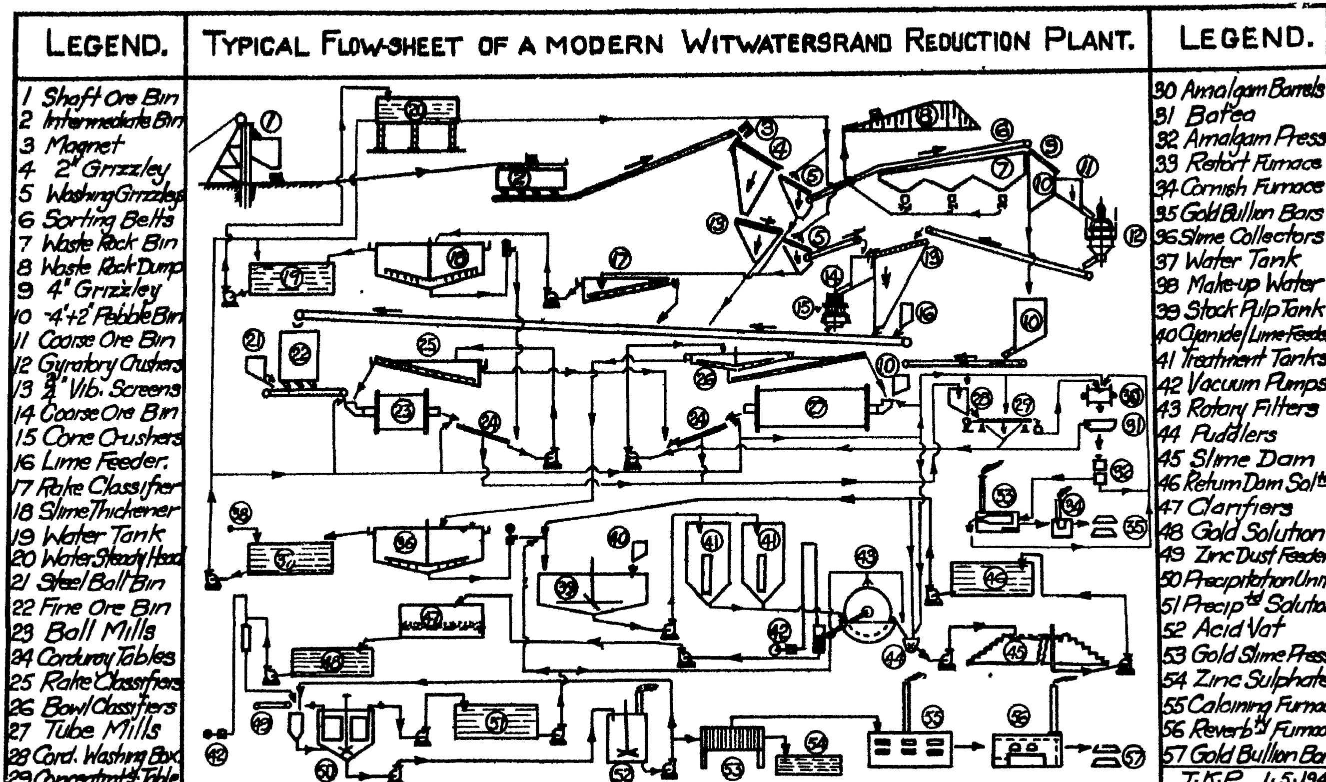
The cyanide process was introduced in 1890 and at the present time it is the most important method of recovering gold on the Witwatersrand. The process consists essentially in bringing the gold into intimate contact with a cyanide solution, which dissolves the gold just as water would dissolve sugar from a mixture of sand and sugar, and then separating the gold-bearing solution from the barren solid residue which is discarded. The gold in the solution is then recovered by being precipitated on zinc, the resulting black gold slime being collected, acid treated and smelted to give gold bullion.

The cyanide process was initially applied only to the more sandy portion of the amalgamation tailing, which brought the total overall recovery by amalgamation and cyanidation up to about 85 per cent. with the result that concentration and chlorination were soon abandoned. At that time there was no known economic method for the treatment of the slimy portion of the amalgamation tailing but the decantation method of treating the slime with cyanide solutions was successfully introduced in 1896 with the result that the previous policy of minimizing the production of slime was abandoned in favour of producing as much slime as possible, thereby releasing more of the fine gold in the ore and improving the percentage recovery.

Finer grinding was facilitated by the introduction of tube mills in 1904 and, with improving tube mill efficiency, the relative importance of the tube mill in the milling circuit became increasingly greater, which, coupled with improved crushing machinery, finally eliminated stamp mills from all new plants erected after 1918. In a similar manner, the improvement in grinding which resulted from the greater number of tube mills brought into use, coupled with improved classification, finally led to the treatment of the finely ground ore by all-sliming methods to the complete exclusion of sand treatment in all plants erected subsequent to 1918. The treatment of the slime by cyanidation was improved by the adoption of air or mechanical agitators and the decantation process from 1910 onwards was replaced by suction filtration methods of separating the gold bearing solution from the residual slime. Since 1910, also, zinc dust for the precipitation of gold from the cyanide solutions has been gradually replacing filiform zinc.

In a modern Witwatersrand reduction plant, of which a flow-sheet is submitted, the ore delivered to the crusher station is divided into approximately plus 2in. and minus 2in. fractions and the former is washed and the obvious non-gold bearing rock is hand-picked therefrom and rejected. The greater portion of the ore is then crushed to pass a ¾in. screen and the crushed product is ground wet to fine grit in primary cylindrical mills in which the grinding medium is either steel balls and/or lumps of ore about 6 inches in diameter, locally termed tube mill pebbles, which are specially selected in the crusher station. The pulp flowing out of the primary mills may pass over corduroy strips before being elevated to mechanical classifiers from which the coarser grit is returned to the primary mills and the finer portion overflows to other classifiers. From the latter, the coarser fraction is raked to secondary cylindrical mills, in which the grinding medium consists of relatively small pieces of ore, i.e., tube mill pebbles about 3 inches in diameter, which, like the large pebbles, are separated in the crusher station. The outflow from these mills may also pass over corduroy strips before being elevated to the same secondary classifiers from which, if still insufficiently ground, it is returned to the secondary cylindrical mills. The overflow from these classifiers represents the ore after it is sufficiently ground and this flows to slime collectors.

Where corduroy strips are used, these are washed approximately every three hours and the pyritic concentrate therefrom is dressed daily on a shaking table of the Wilfley type and the resulting enriched concentrate is amalgamated. The amalgam is retorted, the mercury being thereby recovered for re-use and the gold-bullion is melted, cast into bars containing about 90 per cent. gold and sent to the Rand Refinery where it is purified.


TYPICAL FLOW-SHEET OF A MODERN WITWATERSRAND REDUCTION PLANT.
LEGEND.
1 Shaft Ore Bin
2 Intermediate Bin
3 Magnet
4 2" Grizzley
5 Washing Grizzleys
6 Sorting Belts
7 Waste Rock Bin
8 Waste Rock Dump
9 4" Grizzley
10 -4"+2" Pebble Bin
11 Coarse Ore Bin
12 Gyratory Crushers
13 3/4" Vib. Screens
14 Coarse Ore Bin
15 Cone Crushers
16 Lime Feeder.
17 Rake Classifier
18 Slime Thickener
19 Water Tank
20 Water Steady Head
21 Steel Ball Bin
22 Fine Ore Bin
23 Ball Mills
24 Corduroy Tables
25 Rake Classifiers
26 Bowl Classifiers
27 Tube Mills
28 Cord. Washing Box
29 Concentrat^s Table
LEGEND.
30 Amalgam Barrels
31 Batea
32 Amalgam Press
33 Retort Furnace
34 Cornish Furnace
35 Gold Bullion Bars
36 Slime Collectors
37 Water Tank
38 Make-up Water
39 Stock Pulp Tank
40 Cyanide/Lime Feeder
41 Treatment Tanks
42 Vacuum Pumps
43 Rotary Filters
44 Puddlers
45 Slime Dam
46 Return Dam Sol^tn
47 Clarifiers
48 Gold Solution
49 Zinc Dust Feeder
50 Precipitation Units
51 Precip^td Solution
52 Acid Vat
53 Gold Slime Press
54 Zinc Sulphate
55 Calcining Furnace
56 Reverb^ty Furnace
57 Gold Bullion Bars
T.K.P 1.5.1944

In the slime collectors the solids settle to the bottom and the clear solution overflows and is returned for re-use in the grinding circuit. The settled slime is removed from the collectors either continuously or intermittently and transferred to the treatment tanks wherein the slime is agitated with cyanide solution sufficiently long for the dissolution of the gold, which normally requires about 16 hours. Thereafter, the gold-bearing solution is separated from the residual slime by means of vacuum filters and, after clarification by gravitating through sand filters, the gold-bearing solution is de-aerated and brought into contact with zinc dust in another type of vacuum filter. The gold remains with the excess zinc in the precipitation units and the gold-free cyanide solution is re-used for treating a fresh charge of slime. The zinc-gold slime is removed from the precipitation units about once a fortnight, treated with sulphuric acid and filter-pressed. The zinc sulphate produced is used in conjunction with other chemicals for timber preservation. The pressed gold slime is then calcined, smelted with suitable fluxes in graphite pots equipped with clay liners, and poured into moulds, the resulting gold buttons being melted and cast into gold bars; or, without calcining, the gold slime is charged into a pan-furnace with the necessary fluxes to produce a lead bullion, containing about 10 per cent. gold. The lead is then oxidised to litharge which is re-used in the pan-furnace and the resulting bullion is cast into bars. The gold bars, containing about 88 per cent. gold, are despatched to the Rand Refinery for purifying as in the case of the bullion from amalgam.

Although no large stamp mill has been erected on the Witwatersrand since 1918, it has not been economically attractive to scrap existing crusher stations and stamp mills and to substitute modern crushing equipment and tube mills therefor. Thus of the forty-seven large producing Companies in 1943, twenty-six of them were still using large stamp mills. Similarly twenty-five of these Companies were using sand treatment plants. Thirty-four Companies make use of corduroy concentration. There are now virtually no large reduction plants where the decantation process of slime treatment is still practised and filiform zinc precipitation installations are now in the minority.

In 1943, the forty-seven producing mines milled an average of 106,300 tons per mine per month. The total gold recovered in 1943 amounted to 12,281,855 fine ozs., which at 8 guineas per ounce is equal to 103 million pounds. This recovery is equivalent to 4·097 dwts. gold per ton. The gold content of the residues averaged 0·181 dwt. per ton so that the ore, after being subjected to surface sorting, contained 4·278 dwts. gold per ton, from which the recovery was equivalent to 95·77 per cent. On the individual mines, the ore value varied from about 2·18 dwts to 11·72 dwts. gold per ton milled and the residues from 0·09 dwt. to 0·38 dwt per ton. The percentage gold recovery varied from 93½ per cent. to 97½ per cent., depending upon the original ore

value, the efficiency of the reduction plant and the amenability of the ore to treatment.

As has been stated, the Consulting Metallurgist is guided by the past history and by the performance of existing reduction plants when conducting a laboratory investigation on the ore-samples obtained from the developing mine.

Several of the Mining Groups are equipped with up-to-date chemical and metallurgical laboratories wherein this investigation would be conducted. The sample would be subjected to hand sorting and all of the obvious waste-rock over 2 inches in size would be washed and the grit, etc., therefrom returned to the sample. The rejected waste would be weighed and assayed and its percentage weight of the whole determined. The remainder of the sample would then be crushed down to minus ¼in. and thereafter thoroughly mixed and quartered down to give a representative portion for the determination of its gold, silver and pyritic content and any other mineral it may be suspected to contain, which might adversely affect gold extraction. Small portions of the representative sample would then be ground in a tube mill to various degrees of fineness and subjected to amalgamation, flotation and cyanidation tests. The results from these tests would indicate whether or not cyanidation by itself or in conjunction with amalgamation is a satisfactory method of treatment or whether, due to the presence of some abnormal constituent, the flotation process should be adopted. Thereafter, provided the laboratory is adequately equipped, as several are, confirmatory results would be sought by treating larger portions of the sample in a semi-working scale unit wherein large scale operations could be closely copied.

In some Witwatersrand ores, the presence of graphitic shale demands that the flotation process should be investigated fully but generally it will be found that the installation of a flotation unit cannot be justified. If the ore tested is typical of Witwatersrand ores, it will contain about 2 per cent iron pyrite and it will be found that, owing to the close association of the gold and the pyrite, it is desirable to subject the pyritic portion of the ore to preferential grinding. Fortunately this is automatically achieved in continuously operating plants by the fact that the relatively high specific gravities of the pyrite and the gold cause them to settle rapidly in the classifiers, thus ensuring their frequent return to the grinding mills with the result that both are ground exceedingly fine before they can escape to the cyanide section.

If the ore is truly representative of Witwatersrand ores, the Consulting Metallurgist will find that it is amenable to treatment by cyanidation with or without the inclusion of corduroy concentration and that the extraction improves with finer grinding. There comes a time, however, when the cost of the increased grinding exceeds the value of the increased gold recovery and

thus the degree of grinding is restricted by economic factors. It will probably be found, however, that it is economic to grind to about 75 per cent.—200 linear mesh and that, since such a product can be treated in entirety by all-sliming methods, a sand treatment plant need not be installed.

With the results of the metallurgical investigation and a knowledge of the performance of the reduction plants of neighbouring mines, the Consulting Metallurgist is in a position to proceed with the formulation of the flow-plan and the design of the proposed reduction plant for the new Company. In this connection, he must give close consideration to the following factors:—

(1) Capacity of Plant.
(2) Capital Cost of Plant.
(3) Working Cost of Plant.
(4) Gold Content of Residue.
(5) General Considerations.

These five factors which will now be discussed, are closely allied, each having a considerable bearing upon the others. For example, a well-built plant involving a large capital expenditure would probably cost less to maintain per ton milled than a low-priced plant. Under certain circumstances, the latter plant, due to comparatively coarse grinding, might actually cost less to operate per ton milled but this benefit would be entirely lost by the increased gold content of the residues. Obviously the aim of the Metallurgist is to ensure maximum profit for the Company and therefore he will endeavour to regulate the capital cost of the reduction plant so that the capital amortisation charge per ton milled, plus the operating cost per ton milled, plus the value of the gold in a ton of residue will amount to the absolute minimum.

(1) Capacity of Plant.

The Consulting Metallurgist will be instructed as to the size of the plant required and although there is a growing tendency to erect a relativelly small plant during the development stage of the mine, it is here assumed that the proposed plant will have a capacity of 100,000 tons per month, the latter being approximately the average size of plant for the existing producing mines of the Witwatersrand. The erection of a small plant in the early life of a mine has the merit that it permits a large scale investigation to be made on representative ore into the most suitable method of treatment and that it is then not too late to incorporate any beneficial modifications in the ultimate plant. It is true that the final capital cost may be somewhat increased by building the plant in two or more stages but this defect has been met to some extent by the modern tendency to erect the milling section in a series of independent units, each of about 25,000 tons per month capacity. However, commencing gold

production with a relatively small plant has a positive adverse effect on ultimate profit to the Company by the fact that any capital expenditure incurred after gold production has commenced can, by Government Income Tax Act, only be redeemed over the estimated life of the mine as determined by the Government Mining Engineer whereas all pre-production capital may be redeemed over a period of ten years (see later).

(2) Capital Cost of Plant.

The size of a modern Witwatersrand mine is such that it is reasonable to assume that it will have a production life exceeding twenty years and therefore substantial buildings and plant are usually justified. On this basis, a plant with a milling capacity of 100,000 tons per month would normally cost approximately £600,000 and, since the whole of this money must be raised by the Company itself, it is necessary that it be ultimately redeemed out of working profits. The existing Income Tax Act permits a Mining Company, which started production subsequent to 1935, to redeem its total pre-production capital expenditure over a maximum period of ten years and, in view of the relatively high rate of taxation imposed upon Mining Companies and because of the possibility of the life of the mine being unexpectedly and suddenly terminated, it is advisable to make full use of this provision in the Act. To redeem £600,000 over ten years at 4 per cent. requires an amount of 14·8 pence per ton milled to be abstracted from gross profits during the ten years. If the plant were to cost £500,000 or £700,000, the amortisation cost per ton would be 12·3 pence or 17·3 pence respectively and the Metallurgist must give close attention to these charges when considering the effect of modifications in the capital cost of the plant on working costs and final residues.

The relatively high capital cost of a stamp mill and a sand plant would be factors which would influence the Metallurgist in omitting these from his recommended flow-sheet. Other factors influencing his decision in this matter would, of course, be that modern crushing machinery is no more expensive to operate per ton crushed and that much less water is required in the grinding circuit when stamps are omitted with consequent saving in pumping and classifier equipment. The omission of sand treatment plant is justified by the improved residue which is obtained by grinding the ore so fine that the whole of it can be treated as a slime product.

(3) Working Cost of Plant.

In normal times, the operating costs in a modern Witwatersrand plant dealing with 100,000 tons per month approximate 33 pence per ton milled. The cost of grinding would obviously decrease with the adoption of coarser grinding but, if the latter is carried to the stage that separate sand treatment becomes necessary, then it would be found that there would be no

TABULATION A: EFFECT OF WORKING COST ALLOWANCE ON TAXATION.

Hypothetical Case.	R.	S.	T
	Working Cost Allowance.		
	Normal. £'s.	Increased by £100,000. £'s.	Decreased by £100,000. £'s.
(a) Mining Revenue:			
From minerals produced ..	2,200,000	2,200 000	2,200,000
From house rents, etc.	5,000	5,000	5,000
Total Mining Revenue ...	2,205,000	2,205,000	2,205,000
(b) Allowable Mining Expenditure Working Costs	1,400,000	1,500,000	1,300,000
Less donations, etc., disallowed .	10,000	10,000	10,000
	1,390,000	1,490,000	1,290,000
Less items charged to working costs, now transferred to capital expenditure ranking for redemption	30,000	30,000	30,000
	1,360,000	1,460,000	1,260,000
(c) Gross Profit or Dutiable Amount (a – b)	845,000	745,000	945,000
(d) Capital Redemption Allowance ...	100,000	100,000	100,000
(e) Taxable Mining Income (c – d) .	745,000	645,000	845,000
(f) Non-Mining Revenue	4,000	4,000	4,000
(g) Taxable Income (e + f)	749,000	649,000	849,000
(h) Total Income Tax:			
(k) Normal Tax 3/- per £ of g ...	112,350	97,350	127,350
(l) Special Contribution 22·5% of c	190,125	167,625	212,625
(m) Graduated Tax:			
$y = 40 - \frac{500}{x}$			
$x = \frac{(e)}{(a)} \times 100$	33·7868	29·2517	38·3220
∴ y = ...	40–14·7987	40–17·0930	40–13·0473
∴ y = ...	25·2013	22·9070	26·9527
y % of (e)	187,750	147,750	227,750
Total Tax (k + l + m) ...	490,225	412,725	567,725
Total Tax % of Gross Profit (c)	58·01	55·40	60·08
Increase or Decrease in Taxation	Nil	–77,500	+77,500

improvement in the overall working cost. Conversely, costs would be higher where very fine grinding is necessary for a satisfactory residue and obviously grinding and treatment costs are affected by the size, hardness and refractory nature, or otherwise, of the ore. Working costs are also affected by the nature of the plant, the means adopted for the transport of ore products and the distances the latter have to be transported. Large compact units are more economical to operate than a diversity of small units and labour saving devices reduce the labour force with beneficial effect on working costs.

Any reduction in working costs increases the gross profits by a like amount, but unfortunately, under the present system of mining taxation, whereas the Government takes about 58 per cent. of the overall gross profits in the form of taxation it nevertheless takes approximately three-fourths of additional profits and for this reason the incentive to improve working costs is somewhat dampened. This is exemplified in Tabulation A wherein the financial data are given for a hypothetical non-lease mine. In Case R, with normal working costs, the overall taxation amounts to 58 per cent. of the total gross profit. However, if all factors remain unchanged except that the working costs are increased by £100,000, it is disclosed in Column S that the taxation is decreased by £77,500. This is equivalent to the Government paying 77·5 per cent. of the increased working cost and the mine paying only 22·5 per cent. Conversely, if the working costs are decreased by £100,000 (Column T), it is disclosed that the taxation increases by £77,500 so that the shareholder gains only 22·5 per cent. of the saving that is effected, the Government receiving the balance. Of course, this state of affairs ought not to dampen the keenness to reduce working costs but it undoubtedly has that unfortunate tendency.

(4) Gold Content of Residue.

Just as in the case of working costs, if a mine succeeds in improving the gross profit by a reduction in the gold content of the residue, the Government takes approximately three-fourths of the monetary value of the improvement and the shareholder benefits only to the extent of about one-quarter.

Under normal Witwatersrand conditions, with a modern reduction plant, the residue value from a 4·3 dwts. per ton ore would be approximately 0·129 dwts. per ton, equivalent to an extraction of 97 per cent. The residue would, of course, be higher or lower with coarser or finer grinding.

(5) General Considerations.

Although the final flow-sheet of the reduction plant will appear to be relatively simple, as it will merely consist of a crusher station in which the ore will be reduced to minus ¾ inch, a cylindrical mill grinding plant, with or without corduroy con-

centration, and an all-slime cyanidation plant, there are nevertheless many further decisions to be made by the Consulting Metallurgist in collaboration with the other Consultants.

In the first place, a site must be chosen for the plant. Most mines have at least two shafts which may be situated a considerable distance from each other and it is probable that ore will be hoisted to the surface at more than one shaft. In such circumstances, it is desirable to locate the reduction plant adjacent to the shaft which will deal with the greater portion of the ore and to transport the ore on the surface from the other shafts thereto. For the latter purpose, steam locomotives hauling 50 ton hopper wagons and endless rope haulages equipped with trucks up to 3 tons in capacity are most favoured. Aerial ropeways on the Witwatersrand are only conspicuous by their absence and conveyor belts are seldom used to convey ore over relatively large distances.

The site must contain ground suitable to carry large buildings, bins, crushers, tanks, etc., and at the same time permit fairly large excavations at reasonable cost. A gently sloping site has advantages in lowering the cost of foundations and excavations, although this factor is not of such great importance with the present-day improved methods of pulp elevation.

The main buildings may be of steel and corrugated-iron construction or of reinforced concrete, and tanks may be of steel-plate or concrete. Where large numbers of uniform sized tanks are required, reinforced concrete construction can be justified, although generally, in the matter of capital cost, there is not much difference between the two.

The Consulting Metallurgist must ensure that there will be an adequate water supply and he must decide whether to mill in an alkaline-water or a cyanide-solution circuit. Although cyanide solution milling circuits were popular when all-sliming methods were first adopted about twenty years ago, the modern tendency is to revert to a water circuit. It was found that, although the solution circuit did reduce the overall water consumption, it did not materially assist the dissolution of the gold and it complicated the determination of the gold content of the pulp entering the cyanide section. Moreover, there is less danger of loss of gold through spillages when milling in a water circuit. Cyanide consumption might be greater when a solution circuit is used unless the ore, with its acid tendencies, is given an adequate alkaline water wash before coming into contact with the cyanide solution. With the adoption of a water circuit, the necessity of washing all of the ore in the crusher station falls away and it becomes possible to by-pass the $-\frac{3}{4}$in. fines direct to the tube-mill bins without prior washing, which results in a more even distribution of the gold throughout the 24 hours and less upset in milling conditions generally. This upset would

not be so pronounced were the crusher station to operate throughout the 24 hours, but, usually, to fit in with shaft hoisting periods, the crusher station only operates for 16 hours per day. For the foregoing reasons, the Consulting Metallurgist would probably decide to mill in a water circuit.

The slime which settles in the slime collectors carries approximately 0·6 of a ton of water per ton of dry slime and this water, when transferred to the treatment tanks with the slime, is unavoidably converted into cyanide solution. Thus to avoid an accumulation of cyanide solution in the reduction plant, it is necessary to discard about 0·6 of a ton of cyanide solution with every ton of slime discharged. It has been suggested to interpose rotary filters between the collectors and the treatment tanks to reduce the amount of water converted to cyanide solution but this could only be justified under very abnormal circumstances. Thus the minimum water requirements in a reduction plant are 0·6 of a ton per ton of ore milled, but due to leakages, evaporation, etc., it may be assumed that the normal metallurgical requirement is about 0·8 of a ton of water, which, when milling 100,000 tons in, say 26 days, is equivalent to about 3,100 tons or 620,000 gallons of new water per day. This water might be obtainable from the Vaal River direct, or through the Rand Water Board at about 1s. per 1,000 gallons, but, due to the fact that the mine may have to pump about 2 million gallons of water per day from the underground workings to the surface, an endeavour is usually made to use some of this water, together with whatever surface water can be caught in conservation dams. On the Central Witwatersrand, the water pumped from underground is usually saturated with calcium sulphate due to the use of slaked lime underground to counteract the acidity caused by the oxidation of pyrite. To prevent deposition of calcium sulphate in the pipe columns, the water is delivered to the surface in a slightly acid condition, and, if this water is to be used in the reduction circuit, it is desirable, by further addition of lime, to render it alkaline on the surface and to allow the iron, aluminium and magnesium hydrates to settle out before delivering the clear water to the works. If this is not done, dissolution of gold may be adversely affected due to a deficiency of oxygen in the solutions and an unduly high cyanide consumption may result. On the far Eastern and far Western sections of the Witwatersrand, dolomitic water prevails and the difficulties with acidity are not so pronounced.

The motive power for virtually all machinery in the reduction works will be electricity, which is usually obtainable through the agency of the Victoria Falls and Transvaal Power Company at approximately a third of a penny per unit.

The run-of-mine ore will be stored in relatively large wood-lined steel bins attached to the headgear at each shaft where ore is hoisted. Adjacent to the reduction plant will be a bin, probably constructed in concrete, into which the ore from the

distant shafts will be delivered. From this bin and the adjacent headgear bin the ore will probably be delivered to the crusher station by conveyor belt. The separation into plus and minus 2 inch fractions may be done by grizzley or vibrating screens, but the $-\frac{3}{4}$in. product will undoubtly be separated by vibrating screens. This portion of the ore will not be washed unless it is particularly sticky and messy when, if not washed, it would interfere with the efficiency of the conveyor belts.

The merits or otherwise of sorting out waste rock have long been debated on the Witwatersrand but the modern tendency is to retain sorting. The washings from the plus $\frac{3}{4}$in. rock may be screened on a $\frac{1}{4}$in. screen, the plus $\frac{1}{4}$in. joining the ore being delivered to the tube-mill bins and the undersize entering a straight rake classifier or the washings may pass direct to the latter. The raked product therefrom will pass on to the tube-mill bins and the overflow will either pass direct into the grinding circuit or finally reach this circuit via a Dorr thickener tank, the water therefrom being returned to the crusher circuit.

The crushing will probably be effected in two stages, jaw or gyratory crushers being used for the first stage and a variety of the latter, cone crushers, for the second. The product from the secondary crushers may be delivered direct to the tube mill ore bins without further screening.

The tube mill pebbles will be separated by mechanical means and delivered to storage pebble bins, from which the pebbles will be withdrawn by conveyor belt or truck when required.

The crushed ore will be delivered by conveyor belt to the tube-mill feed bins, equipped either with a tripper unit or a shuttle belt to permit delivery of ore to any part of the bin. The feed will be delivered to the ball mills or tube mills by slow-moving conveyor belts, one for each mill. Each conveyor belt in the crushing and grinding sections should be equipped with water sprays to keep it clean and so prolong its life.

Two stage grinding is mostly used and would probably be adopted. Ball mills for the first stage are becoming increasingly popular because of the scarcity of suitably sized ore pebbles and the cost of separating these relatively large pebbles and the excessive wear and tear in transporting them to the tube mills. Ball mills have another important advantage in that there is much less fluctuation in performance with a ball mill than with a tube mill because the ball load never varies to anything like the extent possible with a pebble load in a tube mill. However, notwithstanding these advantages, it is difficult to justify the use of balls from an operating cost point of view and primary tube mills are likely to be installed in some future plants where conditions are suitable.

Many types of drive are in use on the Witwatersrand for ball and tube mills. In most cases the shell of the mill is

equipped with a spur wheel which is driven by a pinion mounted on a pinion shaft. The latter may be driven by a directly connected slow-speed motor or the power may be transmitted to the pinion shaft by means of a high-speed motor either directly connected to a reduction gear-box or by means of belts with suitably sized pulleys. In a few cases, the motor is directly connected to a reduction gear-box which drives a shaft directly connected to the centre of the discharge end of the mill; thus the exposed pinion and spur wheel are dispensed with. This centre drive type has much to recommend it, especially where corduroy tables are not used and where reject pebbles are not removed from the pulp stream. However, in modern plants, the most widely used system of power transmission is through a reduction gear-box to a pinion and spur wheel.

The largest ball mills in use on the Rand are 9 feet in diameter by 10 feet long, driven by 450 h.p. motors. With many base metal ores, overgrinding of the ore has an adverse effect on extraction and, for this reason, a quick passage through the ball mill is necessary with frequent return thereto of that fraction of the ore still insufficiently ground. For this reason the diameter of a ball mill usually exceeds its length. However, on the Witwatersrand, overgrinding is not detrimental to gold extraction and therefore there is no strong reason why the length should not exceed the diameter. In the last plant to be brought into commission, ball mills 6 feet 6 inches in diameter and 12 feet long, driven by 300 h.p. motors, are functioning satisfactorily. Ten such ball mills would be desirable for the primary grinding in a plant dealing with 4,000 tons per day and their performance would undoubtedly justify their installation.

The largest tube mills in use on the Rand are 8 feet in diameter by 16 feet long, but tube mills 12 feet in diameter by 16 feet long have been suggested for the future. However, the most popular mill is 6 feet 6 inches in diameter by 20 feet long and there appears to be no good reason to depart from this size. The latter would require a 300 h.p. motor, which is the same as that for a 6 feet 6 inches by 12 feet ball mill and, in conjunction with ten such ball mills, the proposed plant would require ten 6 feet 6 inches by 20 feet tube mills.

The grinding plant consisting of ten primary and ten secondary mills would, with advantage, be divided into only two complete units each with five primary and five secondary mills. In this way, distribution of pulp would be improved and the height to which the pulp would have to be elevated would be less than with the whole plant functioning as one unit. Where there are too few mills in each unit of the grinding plant, the failure of any one mill tends to throw the other mills and their classifiers out of balance but this would not apply with ten mills in the unit. Each mill should be equipped with its own classifier, the spiral or rake type for the primary circuit and the Bowl type for the secondary mills.

On the Witwatersrand, pulp is elevated by tailings wheel, hydraulic lift, air lift and by centrifugal pump, the latter being the most popular. Undoubtedly centrifugal pumps would be installed throughout the proposed plant, with the probable exception of the Dorr thickener elevating pumps, and wherever practicable the pumps would be rubber lined. There would be two pumps to each set of five mills, one operating and the other a standby and all other large pumps would have spare standby units.

In the past, it has been common practice to screen out plus ⅜in. pieces of rock from the pulp issuing from the grinding mills and to return these rejects by means of conveyor belts, trucks or native carriers to the crusher station, the stamp mill or the tube mills. However, there is now a tendency to allow these rejects to pass on to the pumps to be elevated to the classifiers, whence they are returned direct to the grinding mills. In some cases, where corduroy tables are used, the pebbles are separated, as in the past, but are allowed to join the stream again at the foot of the corduroy tables.

Of the forty-seven producing mines on the Witwatersrand thirty-four use corduroy to remove the coarser fraction of the gold and in this way 36 per cent. of the total gold recovery on the Rand is effected. In plants where corduroy is used, the gold recovery by amalgamation averages about 50 per cent. of the total gold recovered, but this percentage varies from less than 35 per cent. on the Far East Rand to over 60 per cent. on certain other mines. The cost of corduroy concentration and amalgamation amounts to about 1d. per ton milled, but this is compensated to a small extent by the recovery of osmiridium and the quicker realization of the gold. However, the main advantages of corduroy concentration are that it impoverishes the grinding circuit and that it reduces the value of the pulp to be cyanided to about half. Moreover, by ensuring that no coarse gold is permitted to pass over to the cyanide section, it has a steadying influence on the cyanidation residues. Taking the foregoing facts into account, the probability is that the Consulting Metallurgist would incorporate corduroy in at least the secondary tube milling circuit, if not in both the primary and secondary circuits.

Intermittent and continuous slime collectors are both used on the Witwatersrand, with a decided preference for the continuous type. Of the latter, tanks are in use up to 70 feet in diameter, and 100 feet diameter tanks have been suggested. However, for a plant dealing with 100,000 tons per month, there seems to be no strong reason to exceed 70ft. diameter tanks, of which ten would suffice. A few double-deck Dorr thickeners are in use but these have not been very satisfactory and, since there is usually no restriction of space when laying out a plant on the Witwatersrand, the single-deck type is much to be preferred.

Dorr agitators or Brown tanks are commonly installed for the treatment of the slime, the former up to 50 feet and the latter up to 33 feet in diameter. From the point of view of capital cost and subsequent maintenance, Brown tanks would probably be recommended by the Consulting Metallurgist. Although some plants have adhered to 15ft. diameter Brown tanks, the larger diameter tanks have proved satisfactory even with the centre air lift column reduced to half the height of the tank. It is not uncommon to operate the Brown tanks in series but a more positive slime tonnage measurement can be obtained if the tanks are used quite independently of each other. For this reason the latter system is to be preferred. The Brown tanks are used, with advantage, as pulp storage tanks for feeding the rotary filters and, under the latter system, a total of seven 33 feet diameter by 45 feet deep Brown tanks would probably suffice for the proposed plant.

Although, the Butters intermittent filtration system of separating the gold-bearing solution from the treated slime is operating on many mines, the majority have installed continuous rotary filters and the latter are to be preferred. The popular size is 14 feet in diameter by 16 feet long. This size has proved satisfactory and ten would probably be required. The filters would be arranged in pairs, each pair delivering the residue cake into a mechanical pulper to which gold-free cyanide solution or solution returned from the slime dam or water would be added and from which the diluted pulp would gravitate to the residue pumps and be delivered therefrom to the slime residue dam.

A slime dam for stability reasons, should not rise more than about 6 inches per month and to conform to this requirement a slime dam area of about 100 acres would be required for 100,000 tons per month.

With the adoption of all-sliming, the more granular nature of the slime has increased the tendency for the outside walls of the slime dams to crumble and for the solution to percolate right down to the soil and to emerge therefrom at the toe of the dams. Consequently the soil around the base of the dams is now much wetter than formerly and the danger of breakaways is thereby increased. To meet these new conditions it is desirable that the ground around the dam should be adequately drained away from the dam and it will be found that the construction of drains on the proposed dam site to run off the solution which will percolate down to the soil will be beneficial. Other precautions which should be taken are that the angle of the side walls, including stepping back, should not exceed 40° to the horizontal and that, if possible, the slope of the ground on which the dam is built should not exceed 5°. The dam should be double walled and excess solution should not be retained on the dam longer than necessary. The solution drained off the dam by means of penstocks is usually pumped back to the reduction plant for re-use in the cyanide circuit.

The gold-bearing solution leaving the slime filtration units is usually cloudy and must be refiltered prior to entering the gold precipitation units. For this purpose, sand clarifiers are almost exclusively used on the Witwatersrand and, for the proposed plant, five 50ft. diameter clarifiers would suffice.

All modern plants have adopted the Merrill zinc-dust method of gold precipitation in conjunction with the Crowe mechanical vacuum system of removing oxygen from the clarified solution prior to precipitation. Three 48 leaf precipitation units would be required for the proposed plant.

Several water and solution storage tanks or sumps would be required, equipped with the necessary pumps to deliver the water and solution wherever required.

The cyanide clean-up equipment would consist of two acid vats for the removal of the excess zinc from the gold slime, one 30in. Johnson filter press, one calcining furnace and one reverberatory pot smelting furnace. Although certain gold-bearing by-products, such as the slag from pot-smelting, may be disposed of by selling to By-Products, Limited, a subsidiary Company of the Transvaal Chamber of Mines which operates on a co-operative basis, the plant might, with advantage, be equipped with a pan-furnace and lead cupellation furnace and even a small blast furnace so that all of the by-products can be treated to finality at the mine. The smelting section would also include two retort furnaces if corduroy concentration is adopted.

Usually the rotary filter plant, the precipitation units and the cyanide clean-up and smelting sections are all housed in one building to ensure adequate supervision. In some cases, also, the amalgamation section is included in this building, although this section is sometimes built adjacent to the corduroy house itself, thereby permitting a gravity discharge of the amalgamation residues into the current grinding circuit.

The flow-sheet finally decided upon by the Consulting Metallurgist will probably be very similar to the diagrammatic flow-sheet which is submitted with this address. In normal times, the complete erection of the plant would take about one year, and, when nearing completion, the Consulting Metallurgist would decide upon the personnel to operate the plant. Approximately 36 officials and day's pay employees and 360 natives would be required and he would draw upon other producing mines of his Group for the nucleus of the white labour staff.

When the plant starts up, there would undoubtedly be many adjustments to be made in the performance of machines, etc., but, generally, the plant would soon settle down to give satisfactory performance throughout the life of the mine.

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FILOSOFIE EN WETENSKAP

DEUR
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Presidentsrede aan Afdeling C, gelees 4 Julie 1944.

Inleiding.

Die keuse vir 'n onderwerp vir 'n toespraak voor 'n gemengde wetenskaplike gehoor soos hier teenwoordig, is meesal moeilik. Die maklikste uitweg vir die spreker is om homself te bepaal by 'n onderwerp wat op sy spesiale studiegebied lê. Dit kos hom min moeite en daar bestaan min kans dat die gehoor krities teenoor hom sal staan. Andersyds is dit moontlik om 'n algemene onderwerp te kies, wat meer bekende beelde in die gees van die toehoorders laat verrys. As dit 'n onderwerp is waaroor verskil van mening bestaan en kritiek en bespreking sal uitlok, des te beter. Ek verstout my daarom om laasgenoemde keuse te maak.

Ek gaan dus nie vir u die vooruitgang van een of ander deel van die wetenskap skets nie, maar meer u aandag vestig op die agteruitgang van die openbare agting vir die wetenskap. Dit is nodig dat 'n wetenskaplike so nou en dan uit sy laboratorium kom, sy oë oopmaak en die kleppe van sy ore afhaal, om uit te vind wat die wêreld van hom dink en sê.

Die onderwerp „ Filosofie en Wetenskap " is een wat beter sou pas as 'n onderwerp vir 'n simposium by 'n vergadering van 'n wetenskaplike vereniging, as vir 'n vyf-en-veertig minute toespraak. Ten eerste sou daar dan meer tyd wees om die onderwerp behoorlik te behandel en ten tweede sou dit die verskillende spesialiste in al die takke van die wetenskap en ook die filosowe, 'n kans gee om mekaar aan die keel te pak. My eie kennis van die wetenskap is noodsaaklikerwys beperk tot 'n klein gedeelte. Buitendien moet ek openlik erken dat, as ek my op die gebied van die filosofie begeef, dan praat ek oor 'n onderwerp waaroor ek net so nou en dan iets gehoor of gelees het. Met ander woorde, ek het nog maar net die filosofiese klok hoor lui. Vir die wetenskaplike bioloog, wat die meeste van sy tyd in die laboratorium deurbring, is diepere filosofiese bespieëlinge oor die heelal, op grond van sy waarnemings van die natuur, gewoonlik van minder belang. Hy laat dit met dankbaarheid oor aan die wetenskaplike filosowe of filosofiese wetenskaplikes. Hyself sal alleen gebruik maak van die filosofiese metode wanneer dit hom help om sy waarnemings en die teorieë daaroor te koödineer, sodat hy die probleem waarmee hy besig is, in so'n lig sien dat sy volgende waarnemings hom nader aan 'n oplossing sal bring.

Sy persoonlike filosofie, as 'n mens dit so mag noem, en sy feitekennis sal gewoonlik in nou verband met mekaar staan en gelyktydig ontwikkel. Dit is nie die geval met enkele van die beroepsfilosowe nie. Hulle filosofie loop baie maal die feitekennis ver vooruit. Gee so'n filosoof een vinger en hy neem die hele hand; gee hom een feit en hy sal die hele wêreld daaruit verklaar; gee hom geen feite en hy sal tog nog 'n verklaring van die heelal gee.

Aan die anderkant vind 'n mens baie maal dat die filosoof so besig is met sy filosofie, dat hy onbewus is van die opstapeling van die feitekennis en op dié manier agter raak. Uiteindelik haal hy die agterstand weer in en kan dan weer vooruit hardloop. Dit laat 'n mens dink aan die wedloop tussen die skilpad en die haas. Wie sal in hierdie geval eerste die eindpunt behaal? Is daar 'n eindpunt of sal die wedloop deur al die eeue wat kom so aanhou?

ENKELE FILOSOFIESE BESKOUINGS EN PROBLEME.

Filosofie is grotendeels gebaseer op veronderstelling, oordenking en bespreking. Die filosoof se laboratorium is sy eie bewussyn. Een groep van filosowe beweer dan ook dat die kennis van die werklikheid in ons eie gees woon en ontdek kan word deur bespreking of redenasie. Hulle beskik oor sogenaamde ,,*a priori*'' kennis, wat onafhanklik is van ondervinding en wat ver bo die kennis staan wat deur waarneming en proefneming verkry is, en waarvan die waarheidsgehalte volgens hulle selfs betwyfel moet word. Deur die ,, *a priori*'' kennis alleen is 'n mens in staat om 'n vertroubare beeld van die werklikheid te vorm. Met betrekking tot dié soort filosoof kan 'n mens vra of ,, sy teorie so wyd is as die werklikheid of moontlik dat sy idee van die werklikheid so bekrompe is as sy teorie.''

Nie alleen Descartes en Kant in die verlede, maar ook Eddington, wie se boeke oor filosofie en wetenskap die afgelope jare in die boekwinkels verskyn, val onder die groep van filosowe. Volgens Eddington is die heelal, wat deur die natuurkunde beskryf word, nie objektief nie, maar gedeeltelik subjektief; 'n derivaat van die mens se verstand. Hierdeur sou die toepassing van ,, *a priori*'' kennis geregverdig word. Hy beweer o.a. ,, If we cannot have *a priori* knowledge of the universe, we cannot have *a priori* knowledge that it is objective; and therefore we cannot have *a priori* knowledge that we cannot have *a priori* knowledge of it.'' Dit is die soort van logika waarmee die filosoof die wetenskaplike doodslaan.

Die filosowe het hulle in die loop van eeue besig gehou met baie verskillende probleme, soos o.a. die studie van waardes wat ten grond lê aan 'n bepaalde lewenshouding, met 'n studie van die bewysgronde vir 'n lewe hier-namaals en met die bespreking van die bewyse vir die bestaan van die gees en van materie of stof. Veral die gees en materie was dankbare onder-

werpe vir filosofiese besinning. So is daar bv. die idealisme, 'n soort spiritualisme, wat alleen die gees as werklik en fundamenteel beskou.

Die subjektiewe idealiste onder hulle, soos bv. Berkeley, beweer dat die wêreld om ons en die materie waaruit dit bestaan, nie bestaan sonder die gees wat dit waarneem nie („*esse est percipi*"). Ons neem 'n voorwerp waar deur middel van ons sintuie en die gegewens wat op die manier versamel word is ideë in ons gees. Dit is die sogenaamde kwaliteite van die voorwerp. By waarneming van 'n klontjie suiker sien ek bv. iets wat 'n wit kleur het en 'n onbepaalde vorm. Dit voel rof, dit smaak soet en as ek dit byt, hoor ek 'n krakende geluid. Elke sintuig het dus 'n bepaalde kwaliteit daaraan gegee. Die kwaliteite bestaan elkeen apart, want alleen as ek dit proe weet ek dat dit soet smaak en as ek blind is, weet ek nie dat dit wit is nie. Die subjektiewe idealis is blykbaar in staat om in sy verbeelding die verskillende kwaliteite van die voorwerp as 't ware een vir een af te skil, met die gevolg dat, as die laaste een afgeskil is, daar geen suikerklonktjie meer is nie. Die klontjie suiker het dus geen aparte bestaan op homself, onafhanklik van die bewussyn nie, maar is die produk van ons waarnemings. Op dieselfde manier bestaan die hele wêreld, volgens die idealis, alleen vir 'n gees.

Die antwoord wat Haldane aan dié soort filosoof gee is die volgende: „ If you really believe that you built up the world out of your sensations you have a heavy responsibility, though I must say I congratulate you on some bits of it."

Die storie word vertel van 'n idealis wat by 'n teepartytjie die geselskap deur sy welsprekendheid en logika oortuig het, dat die voorwerpe om hulle heen, die tafels, stoele, koppies, ens., nie in werklikheid bestaan het nie. Toe hy opstaan en weggaan, so word beweer, het hy dwarsdeur die teetafel geloop.

Dit is waarskynlik dat dié soort idealiste nie meer in ons midde is nie. Daar is egter wel 'n ander soort wat objektiewe idealiste genoem kan word. Hieronder kan, bv., James Jeans en Eddington ingedeel word. Volgens Jeans eindig 'n natuurkundige, wat 'n studie van die natuur maak, altyd met 'n aantal wiskundige formules. Die formules beskryf nie die natuur nie, maar alleen ons waarnemings omtrent die natuur. Ons kan dus nie in direkte kontak met die werklikheid kom nie en kom nooit verder as die indrukke wat die werklikheid op ons gees maak. Die vraag is egter wat ons, of wat Jeans, onder „ werklikheid " verstaan. Die werklikheid van die fisika, van die sterrekunde, van die biologie of van almal saam? 'n Werklikheid wat met een woord, of een wiskundige formule, of deur een wet omskryf kan word, of 'n werklikheid wat soos 'n skildery uit verskillende dele bestaan en alleen maar deur die verskillende takke van die wetenskap saam geskilder kan word?

Volgens Jeans, lê 'n begrip van die uiteindelike reële prosesse in die natuur buite ons bereik of, soos hy dit uitdruk,

ons sal nooit in staat wees om die agterkant van ons horlosie oop te maak om te sien hoe die wieletjies draai nie. Die ontwikkeling van die moderne fisika en die groot rol wat die wiskunde daarby speel, het hom tot hierdie sienswyse gebring. Die soort filosofie lyk effens op 'n soort van skeptisisme of vertwyfelings-leer wat probeer bewys dat kennis sonder vertroubare fondament is. Onder die wetenskaplikes kan dit alleen mense soos Jeans bevredig, wat hulle nie met 'n aktiewe soektog na die waarheid besig hou nie, maar hulle meer bepaal by die skryf van populêr-wetenskaplike boeke, wat tot die sogenaamde ,, best sellers '' behoort.

Teenoor idealisme staan materialisme. Daar is ook verskillende skole onder die materialiste, maar in hoofsaak kom dit almal hierop neer dat hulle beweer dat materie, of die wêreld buite ons, onafhanklik van die gees bestaan, dus afgesien of dit deur ons waargeneem word of nie. Die uitwendige werklikheid word, volgens dié idee, beheers deur wette wat ontdek kan word, maar wat nie deur die gees as ontdekker beïnvloed word nie. Ideë in ons gees ontspring na aanleiding van 'n uitwendige werklikheid en hulle waarheid kan deur ondervinding getoets word. Gewoonlik gaan materialisme ook sover as om gees in terme van materie te beskryf en in die uiterste geval, om nie-lewende stof met lewende stof te identifiseer. Uiteindelik sou dus alle lewensverskynsels deur fisies-chemiese analise verklaar kan word. Die vernaamste kritiek op materialisme, is dat dit 'n filosofiese teorie is en dus 'n produk is van die gees, die onafhanklike bestaan waarvan deur materialisme ontken word. Ons kan dus nie weet of dit waar is nie. Buitendien is materialisme 'n onaangename gedagte en word in die gewone lewe as 'n soort skeldnaam gebruik.

Die vrae bly onbeantwoord: Is gees materie, of is materie gees? Het ons te doen met 'n dualisme van gees *en* materie of met 'n monisme?

Die maklikste, mees onwetenskaplike en onfilosofiese antwoord op die vrae word gevind in die volgende aanhaling uit 'n roman van Margaret Irwin: ,, Though all the theologians in the universe inquire: , What is matter?' you will reply , Never mind.' And should they further desire to ask: , What is mind ' you answer: , No matter.' '' Dit is omtrent hoe 'n mens soms voel na 'n bestudering van al die voor- en teenargumente in verband met idealisme en materialisme. 'n Mens weet tog aan die end nie wat waar is nie.

Dieselfde geld ook vir baie ander filosofiese teorieë of probleme. 'n Oplossing wat een filosoof bevredig, wek die heftigste teenstand op van ander. Dit lyk of soveel hoofde, soveel sinne, hier van toepassing is. Dit is alleen die beroepsfilosoof wat sy pad in die labarint van filosofiese sisteme kan vind. In werklikheid lê die waarde van die filosofie vir 'n wetenskaplike dan ook waarskynlik meer in die probleme wat daardeur aan die

lig gebring word, as in die antwoorde wat deur verskillende filosowe op die probleme gegee word.

In baie gevalle het dit geblyk dat die taal, wat die instrument is waarvan die filosoof afhanklik is om sy ideë te vertolk, hom in die steek laat en ontoereikend blyk vir sy doel. Die taal, wat ontstaan het deur gebruik in die praktiese lewe, is nie altyd in staat om die abstrakte gedagtegang van die filosoof suiwer weer te gee nie. Die gevaar bestaan dan dat, in plaas van dat sy gedagtes sy taal bestuur, die taal sy gedagtes beïnvloed en op 'n dwaalspoor bring. So het bv. die feit, dat 'n mens nie alleen kan sê ,, ek droom " of ,, ek dink " nie, maar ook ,, ek droom 'n droom " en ,, ek dink 'n gedagte " Joad laat filosofeer dat 'n droom dus 'n ,, iets " is wat apart van die dromende gees of persoon bestaan. As die metode verder deurgevoer word, sou daardeur die bestaan van baie eienaardige dinge afgelei moet word.

Selfs in die lewe van gewone mense is die verskillende gebruike van taal en die verskil in betekenis wat persone aan woorde heg, die oorsaak van baie onnodige argumente en onaangenaamhede. Vra aan 'n aantal persone wat hulle verstaan onder ,,vryheid," ,, opvoeding," ,, kommunisme," ,, wêreldorde," ens., en u sal waarskynlik vind dat baie van hulle nie in staat is om 'n duidelike definisie daarvan te gee nie en dat die meeste nie dieselfde betekenis aan dieselfde woorde heg nie Ons laat baie woorde oor ons tong rol sonder dat ons aan onsself rekenskap gee van wat ons eintlik bedoel.

Waarom begeef ek my dan vandag in my onkunde op die gevaarlike terrein van die filosofie? Hoofsaaklik omdat as 'n mens 'n kykie neem in die boekwinkels en biblioteke, 'n mens sal vind dat aan die publiek in die afgelope jare 'n wonderlike mengsel van wetenskap en filosofie opgedis word. Sekere dele of teorieë uit die wetenskap word vereenvoudig en dan op so'n manier voorgestel dat die filosofiese redenasies waarmee dit deurvleg word, vir 'n leek logies daaruit skyn te volg. Die leek en selfs die halfhartige wetenskaplike, wat van die werklike doel en metode van die wetenskap geen besef het nie, word netjies aan die neus gelei in enige rigting wat die een of ander skrywer pas. Dat dit so betreklik maklik is, is waarskynlik ook te wyte aan die feit dat die tyd ryp is vir 'n skeptiese houding teenoor die doel en moontlikhede van die wetenskap.

Invloed van die Wetenskap op die Lewe van die Mens.

Die gewone mens se houding teenoor die lewe en die maatskappy is in afgelope tye al deur verskillende wetenskaplike teorieë beïnvloed. So het hy bv. sekere van die ideë uit die evolusie-teorie van Darwin toegepas om sy houding teenoor sy medemense ten regte of ten onregte te regverdig. Die uitdrukkings ,, Struggle for existence " en ,, Survival of the fittest " het alledaags geword. Dit word selfs beweer dat Marxisme die direkte resultaat is van Darwinisme. 'n Ander voorbeeld is die

leer van Freud. Daar was 'n tyd dat 'n mens bang was om hardop oor 'n droom te praat want miskien sou 'n mens se sondige onderbewussyn daardeur bloodgestel word. Ten derde vind ons dat Einstein met „ relativiteit " 'n nuwe magiese woord geskep het vir die leek. Dit is nie 'n begrip wat alleen op die gebied van die fisika van toepassing gebly het nie, maar blykbaar is die moderne mens, wat in opstand kom teen ou tradisionele wette van moraliteit, in staat om 'n nuwe lewensfilosofie daarop te bou. 'n Mens se gedrag volgens dié beskouing, moenie beoordeel word volgens die ou idee van goed en kwaad nie, maar is die resultaat van die omgewing en van 'n bepaalde plek en tyd.

In plaas van dat wetenskaplike teorieë slegs teorieë gebly het, waarop die wetenskap verdere navorsing en waarnemings kon baseer, is dit deur die leek, en dikwels die filosoof, as 'n waarheid oorgeneem, oordryf en in die algemeen misbruik.

Ook in baie ander opsigte is die invloed van die wetenskap op die lewe van die mens te bespeur. Die vernaamste voorbeelde van dié invloed is algemeen bekend. Ten eerste is die angste vir allerhande goeie en kwaaie geeste, wat in onbekende voorwerpe sou skuil en wat ons voorouers met vrees en bewing vervul het, uit die weg geruim. Ten tweede het verskillende uitvindings, waarby die resultate van wetenskaplike navorsing toegepas is, soos bv. elektriese lig, telefoon, draadloos, moterkarre, vliegmasjiene, ens., ens., die lewe baie makliker gemaak. Baie leke meen selfs dat die uitvinding van sulke soort „ instrumentjies " die omvang en doel is van die wetenskap. Hulle sien geen verskil tussen 'n Edison en 'n Pasteur nie. Hulle weet nie dat in werklikheid 'n wetenskaplike alleen maar soek na bewysbare feite, na 'n kennis van die opbou en werking van die natuur, dus na wat wel genoem word „ waarheid," en dat hy die toepassing daarvan oorlaat aan uitvinders en tegnici.

Ten derde het die mediese wetenskap, met behulp van ander dele van die wetenskap, die mens se vrees vir baie siektes verwyder en hom verseker van 'n langer, meer gesonde en minder pynlike lewe.

Ten vierde het die wetenskap vir die mensheid as geheel grotendeels die vrees vir hongersnood uit die weg geruim, 'n groter verskeidenheid in sy voeding moontlik gemaak en hom die middel tot vermyding van baie siektes en liggaamlike swakte, deur voeding aan die hand gedoen. In vroeëre eeue kon hongersnood en ondervoeding nie verhinder word nie omdat dit die gevolg van onkunde was. Die onkunde is deur die wetenskap amper heeltemaal verwyder. As daar tog nog mense op die aarde is wat honger ly, of wat swak is, of wat sterf as gevolg van 'n verkeerde voeding, dan is dit nie die wetenskap, maar die mens self wat daar skuld aan het. Dit is die mens wat deur sy kleinheid, selfsug of domheid, nie die mag, wat hom deur die wetenskap gegee is, gebruik of kan gebruik nie.

Baie meer opvallend nog vir die leek as al die voordele van die wetenskap, is die misbruik wat van hierdie mag gemaak

word. Baie mense sal as voorbeelde van misbruik ook die draadloos, moterkarre, telefoon, ens., insluit, 'wat deur hulle as instrumente van die duiwel beskou word omdat dit sekere van die waardes aan die lewe sou ontneem het. Die mees uitstaande voorbeelde is egter die instrumente van vernietiging, die mag waarvan die afgelope paar jaar nog duideliker geword het en wat ontstaan het, veral as gevolg van skeikundige en natuurkundige navorsing. Die mag van die mens om te vernietig en om die wêreld te beheers is vandag, deur toepassing van die wetenskap, amper onbegrens. Waar die wetenskap die mensheid dus bevry het van baie angste waaronder dit vir eeue gebuk gegaan het, daar nou 'n nuwe bewuste of onbewuste angs in die plek gekom. Dit is die angs vir die mag wat die wetenskap sal kan ontwikkel. Net soos met'geheime wapens, is dit die onbekende wat vrees inboesem. Die vraag is watter geheime van die natuur die wetenskap nog sal ontsluier en waartoe dit gebruik of misbruik sal word.

Dit is 'n vrugbare bodem wat sekere van die teoloë, filosowe en filosofiese wetenskaplikes, wat óf die wetenskap wil ververkleineer, óf 'n bepaalde filosofie op wetenskaplike ontdekkings wil baseer, vind om te bearbei.

INVLOED VAN DIE MODERNE FISIKA OP FILOSOFIESE BESKOUINGS

Dit is seker geen toeval dat by die filosofiese besprekings alhoemeer die wetenskap tot fisika en sterrekunde beperk word. Op die onmeetbaar grote en die ondenkbaar kleine is die belangstelling gekonsentreer. By altwee uiterstes skiet ons voorstellingsvermoe te kort en eindig ons met 'n paar wiskundige formules wat alleen vir enkele ingewydes verstaanbaar is. Van die heelal sê Eddington: ,, That which is, is a shell floating in the infinitude of that which is not,'' en Jeans beskryf dit as ,, Empty space welded on to empty time.'' Hierdeur word die heelal duidelik omskryf, vir wie dit verstaan. Die beeld kan die moderne mens met net soveel angs vervul as wat die geeste in vuur en water sy voorouers vervul het.

Op die gebied van die ondenkbaar kleine vind ons die atoomkerne, die opbreking waarvan blykbaar sulke ontsaglike hoeveelhede energie kan vrymaak, dat die gees vir die moontlike toepassing daarvan terugdeins. Dit lyk nou asof die fisikus, wat met behulp van die wiskunde hierdie magte ontketen, dit op homself wil neem om, in sy filosofie, vir die wetenskap as geheel te praat. Daar was altyd 'n nouer kontak tussen die filosofie en die fisika, as tussen die filosofie en die ander takke van die wetenskap. Dit het weer duideliker geword nou dat uit die fisika stemme van onsekerheid omtrent die sekerheid van ons kennis opstyg.

Die grootste opskuddings in die fisika, waardeur ou wette van hulle voetstukke afgetuimel het, is verwek deur die relativiteits-teorie en deur die kwantum-teorie. Alleen sekere gedeeltes uit dié teorieë en die konklusies wat daaruit getrek

wòrd, is vir ons bespreking hier van belang, omdat beweer word dat daardeur die kousaliteitsgedagte aangetas word. Voordat ons op dié teorieë ingaan, is dit nodig dat ons eers 'n oomblik stilstaan by wat onder kousaliteit verstaan word.

Dit is nie maklik om 'n bepaalde definisie van kousaliteit te gee nie omdat dit op verskillende maniere geinterpreteer kan word. Ek verlaat my daarom by hierdie bespreking hoofsaaklik op die uiteensettings van Elsbach en H. Jordaan in ,, Handboek van het moderne denken.'' Die ou tradisionele idee van kousaliteit is dat die wêreldtoestand op een oomblik die *oorsaak* is van die wêreldtoestand op 'n volgende oomblik, wat dan die *gevolg* of *werking* van die vorige toestand is. Die een of ander werking word egter nie noodsaaklik bepaal deur een oorsaak nie, maar deur 'n kompleks van oorsake. Oorsaak en werking kan dus nie, soos vroeër wel voorgestel is, in pare gerangskik word nie. Die uiteindelike oorsaak van alle verskynsels en veranderinge gaan terug tot begin van alle gebeure.

As ons die begrip van kousaliteit bestudeer dan sien ons dat daarin 'n tydrelasie en ook 'n aanduiding van bepaaldheid opgesluit is. Dit blyk veral ook uit die volgende definisie van Burkamp: ,, Kausalitat ist eindeutige Determiniertheit des zeitlich Spateren durch das zeitlich Frühere.'' Wat vroeër in die tyd voorhande is, bepaal, bring mee of determineer die latere. In die natuurwetenskappe word ,, kousaliteit '' en ,, determinisme '' dan ook dikwels in dieselfde sin gebruik.

In die tradisionele kousaliteitsbegrip. is buitendien die gedagte aanwesig dat 'n oorsaak 'n soort van sentrum van aktiwiteit is, wat 'n bepaalde werking kragdadig meebring en in die lewe roep. Dit is volgens Elsbach kousaliteit in aktiewe sin. In hierdie geval kan alleen bepaal word wat oorsaak en wat gevolg is as ons weet watter een van die twee aan die ander een vooraf gaan. Oorsaak en gevolg is dus ook onomkeerbaar. As ek nie eet nie, kry ek honger. As gevolg van ondervinding neem ek aan dat die feit dat ek nie geëet het nie, die oorsaak is van my honger en nie dat my honger die oorsaak is dat ek nie geëet het nie.

Die kousaliteitsbegrip bevat tenslotte nog die besef dat daar tussen oorsaak en werking 'n bepaalde ,, legale '' of wetmatige verband bestaan. Dit is volgens Elsbach kousaliteit in legale sin. Hieruit volg ook dat 'n bepaalde oorsaak altyd gepaard gaan met dieselfde werking. Die mening van Sigwart is dat die vernaamste geval van kousaliteit die wisselwerking tussen onsself en ons ongewing is, en Lotze druk dit uit deur te sê, dat alle enkele verskynsels alleen in 'n saamwerkende verband met die geheel van die werklikheid bestaan.

Of die verskil tussen kousaliteit in aktiewe en in legale sin hierdeur baie duidelik is of nie, die feit bly dat die kousaliteitsgedagte oorals in die gewone lewe en in al die wetenskappe toegepas word. Veral in die biologie berus alle navorsing

daarop. Ons vind in 'n organisme, volgens H. Jordan, verskillende faktore wat kousal op mekaar inwerk. Net soos in 'n bepaalde masjien daar bv. 'n suier, 'n silinder, 'n wiel en 'n stoomketel is wat kousaal op mekaar werk en daardeur veranderinge teweegbring, so ook met die faktore in 'n organisme. Elke faktor staan in verband met tenminste twee ander faktore soos 'n skakel in 'n ketting. Kousaliteit is nie die verklaringsmiddel nie, maar is die ontledingsmiddel waardeur ons die verband tussen die faktore of oorsake bestudeer. Die studie van die kousale onderlinge verband tussen die faktore of oorsake is die taak van die biologie.

Laat ons nou nagaan waarom beweer word dat die relativiteits-teorie en die kwantum-teorie die kousaliteitsbegrip aantas. Volgens die relativiteits-teorie is tyd en ruimte geen aparte sisteme nie maar bestaan daar alleen maar een vierdimensionale sisteem, nl. die tydruimte. Daar is geen grenslyn waardeur 'n mens die sisteem in 'n driedimensionale ruimte en 'n eendimensionale tyd kan deel nie. Daar bestaan dus ook geen driedimensionale wêreld, wat 'n serie van agter-een-volgende momente, soos 'n verlede, 'n hede en 'n toekoms, deurloop nie, maar daar is alleen die vierdimensionale kosmos wat bestaan. Die menslike begrippe van ruimte en tyd is dus abstraksies uit die vierdimensionale sisteem. Hierdeur word die ou tradisionele kousaliteitsbegrip in aktiewe sin onhoudbaar vir die wetenskap. Dit word egter partymaal vergeet dat kousaliteit in legale sin nie daardeur omvergegooi word nie. Die wettige verband tussen oorsaak en werking bly dus bestaan, nieteenstaande wat enkele boekskrywers daaroor te sê het nie.

'n Baie ernstiger bedreiging kom van die kant van die kwantum-teorie. By die ontwikkeling van die teorie het naamlik geblyk dat elektrone, of die kleinste deeltjies waaruit materie bestaan, aan die een kant eienskappe vertoon, soos energie en momentum, waardeur hulle die karakter van klein deeltjies besit. Aan die ander kant egter tree daar verskynsels op wat op die oomblik alleen maar verklaar kan word deur golfvelde wat in ruimte en tyd versprei. Dieselfde geld ook vir lig. Gedeeltelik moet ons lig opvat as bestaande uit klein deeltjies, naamlik fotone, maar die golfkarakter van lig is ook duidelik aantoonbaar.

Dit is 'n skynbare paradoks. Die fisikus vind hiervoor nou 'n heel ander oplossing as wat 'n bioloog sou bevredig. Die fisikus verklaar naamlik dat 'n mens 'n elektron nie kan waarneem sonder om die gedrag van die elektron te versteur nie. Om die elektron te kan waarneem moet hy gebruik maak van ander elektrone of van fotone. Maar hierdie ander elektrone of fotone beïnvloed òf die posisie, òf die snelheid van die elektrone wat waargeneem word. Hieruit volg die „onbepaaldheids beginsel" van Heisenberg, dat 'n mens nie die posisie en die snelheid van een elektron gelyktydig kan bepaal of meet nie. Alleen by bestudering van 'n groep elektrone kan deur statistiese analise resultate verkry word. Hiervoor word die golfstelsels

gebruik. As sulke golfstelsels deur die ruimte beweeg, dan beweeg hulle saam met die deeltjies. Die intensiteit van die golfbeweging op verskillende punte in die ruimte, gee 'n maat vir die waarskynlikheid dat in daardie gebiede elektrone aanwesig sal wees. Born noem die golwe dan ook golwe van waarskynlikheid; die waarskynlikheid omtrent die verspreiding van die deeltjies in ruimte en tyd.

Twee gedeeltes uit bogenoemde voorstelling word nou deur verskillende filosowe en teoretici ten volle uitgebuit. Die eerste is dat ons die natuur nie kan waarneem sonder dit te versteur nie, omdat ons waarnemingsaktiwiteit 'n onvermydelike storende omstandigheid is; m.a.w. ons waarnemings van die natuur kan nooit objektief wees nie. Soos ek al eerder aangehaal het, bring dit o.a. Jeans tot sy filosofie van objektiewe idealisme. So bv. sê hy: ,, And now that we find that we can best understand the course of events in terms of waves of knowledge, there is a certain presumption—although certainly no proof—that reality and knowledge are similar in their nature, or, in other words, that reality is wholly mental. We can have no means of knowing the true nature of reality.'' By 'n ander geleentheid sê Jeans: ,, The universe can best be pictured, although still very imperfectly and inadequately, as consisting of pure thought, the thought of what, for want of a wider word, we must describe as a mathematical thinker.'' Dat Jeans tog nog 'n sekere versigtigheid aan die dag lê, maak vir die leek, wat smag na 'n strooihalm om hom te red van die sogenaamde verskriklike werklikheid van die wetenskap, geen verskil nie.

Ook Eddington druk dieselfde gedagte uit deur: ,, Mind is the first and most direct thing in our experience; all else is remote inference.'' Wat 'n heerlike gedagte vir die filosoof of teoloog om verder mee te speel, veral as hy kan sê dat dit uit die mees eksakte van alle wetenskappe voortspruit! Tafels, stoele, ens. bestaan dus uit golwe van waarskynlikheid en leë ruimte. Omdat daar geen metode bestaan en volgens die fisikus, nooit sal bestaan, om 'n elektron ongestoor waar te neem nie, kan ons volgens dié idee, ook die hele natuur en dus alles om ons heen en ons eie liggaam, nie in sy werklikheid waarneem nie. Die werklikheid bestaan egter nie uit 'n menigte loslopende, onafhanklike elektrone nie. Soos Levy dit uitdruk: ,, For an isolated system like an electron we have to justify the neutral existence of these isolations. Thus we have to ask, for example, whether in these circumstances we are entitled to assume the continued persistence of a localised object independently of its speed.''

Die tweede idee wat orals in filosofiese beredenerings gebruik word is die ,, onbepaaldheids beginsel,'' nl. dat posisie en snelheid van 'n elektron nie gelyktydig gemeet kan word nie. Alhoewel dit lyk asof dit meer is as net 'n tegniese moeilikheid, is dit tog eienaardig dat daaruit die konklusie getrek word dat die posisie en snelheid dan ook nie deur sekere faktore of oorsake

bepaal word nie, m.a.w. dat wat ons nie kan waarneem nie, ook nie bestaan nie. As die gedrag van 'n elektron werklik onbepaald is, verval die kousaliteitsidee of determinisme, waarvolgens een toestand 'n ander toestand bepaal. Die posisie en snelheid van die elektrone kan ons nie bepaal nie en dus kan ons niks voorspel omtrent 'n volgende toestand nie.

Vir 'n bioloog beteken 'n geval, waar ons 'n verskynsel nie kan meet of waarneem nie, niks besonders nie. Hy sal dan aanneem dat die verskynsel tog deur 'n aantal onbekende faktore bepaal word en die oorsaak sal wees van 'n volgende toestand. Hy is gedurig op soek na hierdie faktore. Die eerste stap is altyd die analise van verskillende faktore of oorsake. Die tweede stap is dan om deur 'n sintese van die faktore 'n verklaring te vind vir die verskynsel as geheel. Dat 'n sintese dikwels nie moontlik is nie, skryf die bioloog toe aan 'n onbekendheid met al die kenmerke van die faktore en ook aan die feit dat, as faktore tot 'n geheel verbind, hulle nog ander eienskappe openbaar, wat nie sigbaar is as die faktore geïsoleer is nie.

Noudat die fisikus egter op 'n toestand stuit wat vir hom onmeetbaar is, trek hy 'n streep en sê dat van daar af dit ook nie meer deur die ,, natuur '' bepaal word nie. Die feit dat hy deur statistiese analise die toestand met 'n mate van waarskynlikheid kan weergee, gee hom geen bevrediging nie. Die bioloog is gewoond om. as hy met 'n veelheid van faktore te doen het met 'n statistiese analise genoeë te neem. Hy word tog daardeur in staat gestel om voorspellings oor die toekoms te maak. As kousaliteit in die natuur nie van toepassing was nie, sou ons selfs op grond van waarskynlikheid geen voorspellings kon maak nie, maar 'n algemene gaos sou die resultaat wees.

Die fisikus heg blykbaar 'n ander betekenis aan kousaliteit. Born, bv., sê: ,, In the quantum theory the principle of causality must be dropped,'' en verder, ,, In the case of the large bodies of everyday experience we come back to the old law of causality. Position and velocity can be determined simultaneously with sufficient accuracy.'' Hieruit blyk die verskil in sienwyse. Die kousaliteitsbegrip sluit nie in dat 'n toestand deur 'n persoon gemeet word nie, soos Born dit voorstel, maar wel dat 'n bepaalde toestand deur 'n vorige toestand of deur 'n aantal ander faktore veroorsaak word. Aan hierdie kousaliteitsbegrip het die onmag van die fisikus om 'n toestand te meet, nie die minste verskil gemaak nie.

Ander skrywers gaan baie verder as Born en skaf kousaliteit af, nie alleen in verband met elektrone nie, maar doen dit sommer ook vir die natuur as geheel en neem dan nog 'n volgende groot sprong en skaf determinisme in verband met die ,, Wil '' af. Haeckel het ons aan die end van die vorige eeu met onverklaarbare selfversekerdheid vertel: ,, Die geweldige stryd tussen die deterministe en indeterministe, tussen die teenstanders en die aanhangers van die vryheid van die wil, is nou, na meer as tweeduisend jaar, eindelik ten gunste van die eerste beslis.''

'n Dertig jaar later sê Eddington, ewe selfversekerd: ,, So far as we have yet gone in our probing of the material universe, we cannot find a particle of evidence in favour of determinism. There is no need any longer to doubt our intuition of FREE WILL."

Die moderne fisika het egter geen geldige argumente voor of teen die kousaliteitsgedagte of die ,, Vryheid van die Wil " gebring nie. Die hele wetenskaplike navorsing en die daëlikse lewe, soos reeds gesê, steun op die geldigheid van kousale wette. Bertrand Russell druk dit so uit: ,, The principle of causality may be true or may be false, but the person who finds the hypothesis of its falsity cheering, is failing to realise the implications of his own theory. He usually retains unchallenged all those causal laws which he finds convenient, as for example, that his food will nourish him and that his bank will honour his cheques so long as his account is in funds, while rejecting all those he finds inconvenient."

As die skeptiese houding van die objektiewe idealis teenoor die wetenskap algemeen verbrei sou word onder die publiek en onder wetenskaplikes, sou dit min of meer die end beteken van wetenskaplike navorsing, wat tot doel het om die geheime van die natuur te ondersoek. As 'n wetenskaplike navorser deurdring is met 'n gevoel van pessimisme en twyfel kan hy nooit bevrediging in sy werk vind nie. Dit is sy nuuskierigheid, en die bevrediging wat hy daarvoor kan vind, wat hom aanspoor. Daar sal dan 'n tyd kom wanneer kennis gebaseer op waarneming vervang sal word deur ,, *a priori* " kennis.

'n Mens wonder hoe die beeld van die werklikheid sal lyk as daar ten eerste geen waarnemings meer is vir die ,, *a priori* " kennis om op voort te bou nie en ten tweede as hierdie kennis dan in meer as net in die vrugbare brein van Eddington uitgebroei word. 'n Idee van hoe dit sal lyk kan gekry word deur te dink aan die heersende verskil in opinie oor politiek en godsdiens wat hoofsaaklik deur die gees gevoed word. Die warboel waarin ons kan beland word al voorspel deur die voorstel van die voorstanders van ,, *a priori* " kennis dat, as daar twee teorieë is wat sekere verskynsels kan verklaar, ons die eenvoudigste van die twee moet kies. Dit is egter blykbaar moontlik dat selfs Eddington en Einstein kan verskil van mening oor wat die eenvoudigste van twee teorieë is.

WETENSKAP AS 'N STREWE NA MAG.

As die drang tot navorsing uitgedoof word, kan daar nog net een rede vir wetenskaplike navorsing oorbly en dit is die drang na mag. Die drang na mag sal nooit in die wetenskap of in die wetenskaplike self gevind word nie. Pasteur, Darwin, Madame Curie, Einstein of enige andere wetenskaplike se motiewe was van 'n heel ander aard. Dit is egter die gewone mens wat deur middel van sy industrieë of deur middel van die staat, die mag nastreef. As gevolg daarvan sal die toegepaste

wetenskap nog bly bestaan maar uiteindelik moet dit ook, deur gebrek aan die agtergrond wat deur die suiwere wetenskap verskaf word, stadigaan tot stilstand kom.

Dat baie leke van vandag die wetenskap beskou as 'n strewe na mag, blyk o.a. uit 'n boek van Canon A. E. Baker oor ,, Science, Christianity and Truth '' wat so pas verskyn het. Hierin sê hy bv.: ,, Science arose in the attempt to satisfy the practical need of controlling and using our physical environment. It is an artificial creation of the mind, devised not to obtain knowledge or provide truth, but to control nature. It bears fruit but does not bring light. It's soul is utility. It is a labour saving device. Amen,'' sê die wetenskaplike hierop, ,, Dit raak ons nie watter onsin Mnr. X of Y oor die wetenskap skryf nie.'' Dit raak ons egter wel want die publiek en die jong toekomstige wetenskaplikes lees hierdie boeke en die boeke van Jeans, van Joad en andere van dieselfde soort.

Dat die skrywers hierdie houding probeer aankweek deur die wetenskap self as argument te gebruik, blyk uit die volgende aanhaling uit die boek van Baker: ,, Einstein and relativity, Rutherford and Bohr and almost innumerable electron theories of the atom, and not least important, from a philosophical point of view, the notion that natural laws are only statements of statistical averages, and that there is an element of indetermination even at the heart of inorganic matter, have forced plain men to doubt whether science is true.'' 'n Leek, 'n veral 'n teoloog, kan blykbaar nie insien dat 'n wetenskaplike teorie iets anders is as 'n godsdienstige geloof nie. Soos Elsbach dit uitdruk streef 'n geloof na die bevrediging van godsdienstige behoeftes, terwyl 'n teorie streef na waarheid. 'n Wetenskaplike verwelkom daarom enige verandering van 'n teorie waardeur hy nader aan die waarheid gebring word. Dit is vir hom geen dogma waaraan hy krampagtig vasklou nie. Hoe meer teorieë en veral hoe vinniger hulle verander, des .te vinniger is die vooruitgang van die wetenskap.

Nadat Baker 'n voorstelling gegee het van wat die wetenskap is, gee hy ons 'n idee van wat dit in die toekoms mag beteken: ,, Science by itself will lead to tyranny, cruelty, to something joyless, without beauty, without love.'' Dit kan tog egter nie gesê word dat tirannie en wreedheid nie bestaan het voor die ontwikkeling van die wetenskap nie. Wat van die tirannie van die kerk in die vorige eeue, van die tirannie van kapitaal oor werker, van veroweraar oor verowerde? Wat van die wreedheid wat, óf in naam van godsdiens, óf in naam van beskawing gepleeg is? Dit lyk asof ons met ewe veel reg kan sê: ,, Religion without science has led to cruelty, tyranny,'' ens. Dit is egter nie die godsdiens as sulks wat daarvoor verantwoordelik was nie, maar die menslike karakter of gees. Die wetenskap kan help om dit te verbeter deur die mens minder vatbaar te maak vir bygelowe en suiwer emosionele reaksies.

SOGENAAMDE TEKORTKOMINGS VAN DIE WETENSKAP.

Sowel Baker as die bekende filosoof Joad, wie se opinies ook in ons koerante aangehaal word, doen baie moeite om die tekortkomings en beperktheid van die wetenskap aan te toon. Omdat daar volgens hulle sienwyse tekortkomings is, is die wetenskap 'n abstraksie wat nooit die hele waarheid kan bevat nie. Die meeste van hulle argumente openbaar die onkunde wat daar bestaan in verband met die metode en doel van die wetenskap. Ek sal daarom twee kortliks bespreek.

Die eerste argument is dat die wetenskap nie kan verklaar ,, waarom " nie. Want, beweer Joad, as die wetenskaplike sê dat B die oorsaak is van A, dan kan 'n mens weer vra wat die oorsaak is van B. Is dit C dan moet die oorsaak van C weer verklaar word. So gaan dit die hele alfabet af en uiteindelik kom daar 'n punt waar die wetenskaplike geen antwoord meer kan gee nie. Waarom leef ons, waarom bestaan 'n elektron, waarom is 'n koei geen bobbejaan nie. Dit is blykbaar die vrae wat party mense verwag dat die wetenskap ook moet oplos. Sekere filosowe en selfs enkele wetenskaplikes meen soos gesê, dat die hele werklikheid uiteindelik deur een wet of een wiskundige formule weergegee moet kan word. Die wetenskap het egter nog nooit beweer dat daar 'n antwoord gevind is of gevind kan word vir elke ,, waarom " nie, of dat die werklikheid as 'n eenheid begryp kan word nie. Dit is alleen die onwetenskaplike filosoof, wat nie gebind is aan bewysbare feite nie, wat dit kan beweer. Elke klein gedeelte van die waarheid kan alleen deur ontsaglike moeite en inspanning aan die natuur ontworstel word en die wetenskap is slegs aan die begin. Gissings, of daar 'n laaste ,, waarom " bestaan en of ons ooit 'n antwoord daarvoor kan vind, hoort by die teologie of filosofie tuis en nie by die wetenskap nie. Die wetenskap is nie so haastig nie.

Die tweede argument is dat die wetenskap die sogenaamde waardes van die lewe soos skoonheid, vreugde, goedheid, waarheid, ens. verwaarloos en dat hulle tog deel van die werklikheid is. Joad beweer dan ook dat waardes objektief is. Ons kry dus nou die sienswyse dat wetenskap as subjektief, maar waardes as objektief bestempel moet word! Volgens dié idee moet 'n skildery van Pierneef dus dieselfde gevoelens van ontroering wakker roep by 'n Eskimo, 'n Sjinees en 'n inboorling van Borneo, of daar is iets verkeerd met die mense. Wat die houding van die wetenskap teenoor waardes betref, kan ons alleen maar dié soort filosoof daarop wys dat, behalwe sekere aspekte van die gees, wat deur die sielkunde ondersoek word, die wetenskap hierdie probleme, in ieder geval voorlopig, oorlaat aan die filosofie.

Daar is egter geen enkele grond vir die bewering dat die wetenskap die bestaan van waardes in die lewe ontken en daardeur die mens omskep in 'n rekenmasjien sonder gevoelens nie. In vergelyking met die filosoof wat die kwaliteite van 'n voorwerp kan afskil tot daar niks oor is nie, het die wetenskaplike,

wat in die innerlike struktuur en werking van die natuur deurdring, tog seker 'n dieper gevoel vir skoonheid en waarheid. Die wetenskaplike vind sy hoogste bevrediging in die ontdekking van die waarheid. Hy kry 'n besef van die waarde van onpartydigheid, onbevooroordeeldheid en eerlikheid teenoor sy waarnemings van die natuur en dus ook teenoor homself en sy medemense. Hy leer om versigtig te wees in sy vasstelling van konklusies en in die vel van 'n oordeel, selfs oor wat goed en wat kwaad is. Bo al leer hy nederigheid en ontwikkel 'n besef van die beperktheid van sy eie kennis, by beskouing van die grootsheid van die natuur. 'n Wetenskaplike houding teenoor die lewe kan ook alleen maar lei tot groter verdraagsaamheid in teenstelling met die onverdraagsaamheid wat gewoonlik sy oorsprong vind in 'n politieke of godsdienstige geloof. Dit is die lesse wat die wetenskap het om te leer vir wie daar vatbaar voor is.

Vitalistiese Beskouings.

Behalwe die filosofiese opvattings wat hierbo bespreek is en wat die wetenskaplike navorsing as geheel ondermyn, is daar nog 'n paar filosofiese gesigspunte wat spesiaal vir biologiese navorsing 'n gevaar vorm.

In die biologie word gewoonlik twee beskouings teenoor mekaar gestel, naamlik die meganistiese en die vitalistiese. Meganisme, wat in baie opsigte dieselfde is as materialisme, vergelyk die werking van 'n organisme met die van 'n masjien. Die meganiste beweer dat biologiese metodes van ondersoek dieselfde moet wees as in skeikunde en fisika en dat lewe uiteindelik tot fisies-chemiese reaksies teruggevoer kan word. Die tyd laat nie toe dat ek op die sienswyse verder ingaan nie en aantoon dat 'n organisme tog ook sekere eienskappe besit wat nie in 'n masjien gevind word nie. Wat egter ook al teen meganisme as natuurfilosofie gesê word, die feit bly dat die meganiste optimistiese navorsers is, wat baie tot die kennis van die lewendige organisme bydra. Dit kan in ieder geval nie beweer word van die vitaliste nie. Die vitalistiese leer verkondig dat gebeurtenisse in 'n organisme nie verklaar kan word deur natuurlike of meganiese oorsake nie. maar wel deur bo-natuurlike of nie-meganiese oorsake of lewenskragte, wat ingryp in die werking van die organisme. Daar is verskillende vorme van vitalisme, maar almal lewer gevaar op vir biologiese navorsing, omdat hulle sogenaamde verklarings in werklikheid geen verklarings is nie, maar slegs 'n naam vir 'n bestaande probleem is. Vir die persone wat werklik dink dat, deur 'n naam aan 'n probleem te gee dit daarmee opgelos is, word alle navorsing oorbodig. So bv. sê Driesch: ,, Wir haben kurz gesagt nun nichts mehr zu fragen!"

Een vorm van vitalisme is die teleologiese of teliese verklaring waarby die doel van 'n verskynsel die verklaring sou gee vir die bepaalde verskynsel. 'n Begrip wat hieronder val is die begrip van ,, aanpassing." Dit is duidelik dat 'n organisme in harmonie leef met sy omgewing en soos gesê word, daaraan

aangepas is. As sulks is die aanpassing 'n probleem vir ondersoek. As die idee van aanpassing egter gebruik word as 'n verklaring, of as 'n metode om konklusies te trek i.v.m. sekere verskynsels, dan verval 'n mens in allerhande fantastiese spekulasies wat van alle agtergrond ontbloot is. Ons vind bv., dat die soort spekulasie nog baie maal gebruik word in biologiese onderwys op skole.

As 'n verklaring vir lewensverskynsels word deur verskillende persone ook nog ander terme ingevoer, soos bv., ,, dominante " deur Reinke, ,, immateriële impulse," deur Uexküll, ,, élan vital " deur Bergson en ,, entelechie " deur Driesch. Driesch het by sy navorsing oor embriologie resultate gekry wat op daardie tydstip nie gewoon kousaal verklaar kon word nie. Hy het daarom die begrip ,, entelechie," wat oorspronklik van Aristoteles kom, ingevoer. Entelechie sou nie 'n bepaalde krag wees nie maar 'n ordende prinsipe wat die doellose materie doelmatig sou maak en wat spesiaal aktief sou word by enige verstoring. Die gevaar van so'n begrip blyk uit die feit dat Driesch, nadat hy hom in die filosofiese gesigspunt ingeleef het, hom nie meer met navorsing besig gehou het nie. Soos M. van Herwerden dit uitdruk: ,, In den philosoof Driesch is de natuuronderzoeker te gronde gegaan."

'n Ander groep van vitaliste word ook wel organisiste genoem. Volgens hulle is die geheel meer as die som van die dele. In die geheel sou dus iets nuuts ontstaan wat nie verklaar sou kon word deur 'n studie van die dele nie. Hierdie sogenaamde organisasie kan volgens die vitaliste nie verstaan of bestudeer word nie. Dit word nie alleen toegepas op lewendige organisme nie maar ook op die nie-lewende stof. Bv. as waterstof en suurstof verbind en water ontstaan, dan het daar volgens die vitaliste 'n nuwe ,, iets " ontstaan wat nie in waterstof en suurstof aanwesig was nie. Dit het dus uit niks onstaan soos Joad dit uitdruk. Hierdie gedagtegang is al met verskillende name voorsien. Dit is blykbaar o.a. uitgewerk deur G. H. Lewis in die vorige eeu en later deur C. Lloyd Morgan, S. Alexander, A. N. Whitehead, Generaal Smuts en J. S. Haldane uitgebrei, of effens anders toegelig. C. Lloyd Morgan noem sy weergawe daarvan ,, emergent evolution " en Generaal Smuts, soos bekend, het dit ,, Holism " genoem.

Hierdie filosofiese beskouings is voldoende gekritiseer deur Hogben in ,, Nature of Living Matter," deur Levy in ,, The Universe of Science " en deur ander skrywers. Hier kan ons volstaan met weer daarop te wys dat die studie van die kousale onderlinge verband tussen die faktore in 'n organisme, juis die taak is van die biologie en dat dit geen spesiale misterie is, dat die dele van 'n geheel ook nog ander eienskappe openbaar as hulle met mekaar in verband staan as wanneer hulle geïsoleer is nie. Om dit organisasie, holisme of ,, emergent evolution " te noem, gee die probleem 'n naam maar geen verklaring daarvoor nie. Dit bring ons geen stap verder nie, maar werk

steriliserend op biologiese navorsing. Dit word die beste uiteengesit deur J. Needham: ,, The cardinal error, in my opinion, of all vitalists, neo-vitalists, and what we might call 'passive organicists' is that they leave off precisely where the scientific worker ought to begin," en verder ,, If, arriving in front of the heavily fortified living cell, we simply accept the fact of its high organisation as a primary datum, we do no more than sit down before it, and dig ourselves in, but if, advancing boldly to the walls, we blow loud blasts upon the trumpets of mathematical physics, I will not prophesy that what happened at Jericho will happen again, but the odds are heavily in favour of it."

SLOT.

Waar die filosofie die wetenskap 'n dink-metode aan die hand gee kan dit van baie nut wees en kan daarom nie deur die wetenskaplike van die hand gewys word nie. Aan die ander kant moet dit ten sterkste afgekeur word as 'n filosoof in sy ongeduld om 'n oplossing of verklaring te vind, die wetenskap vooruit loop en sogenaamde verklarings gee wat miskien wel die gevoel maar nie die verstand kan bevredig en wat selfs nie as werkhipotese gebruik kan word nie.

Netso min betaam dit die wetenskaplike om hom op die gebied van die teoloog te begeef. Dit lê buite sy bestek totdat hy al die ander ,, waaroms " beantwoord het. Sonder dat dit enige verskil sal maak aan sy navorsing van die natuur kan hy op een punt met Baker saamstem, naamlik waar hy sê: ,, God made me, and all the world. Science may tell us a little of how He did it." Dit is in die eerste plek die doel van die wetenskap.

Uit die voorgaande blyk die algemeen-menslike neiging, wat daar onder ons bestaan om ons besig te hou met sake waar ons nie genoeg van weet nie. Ek self is oortuig dat, as ek al die boeke, of selfs maar die helfte van die boeke oor filosofie en fisika sou gelees het, en as ek die wiskundige formules van Einstein sou verstaan het, voor ek met hierdie toespraak begin het, ek nooit die moed sou gehad het om my mond oop te maak nie. Ek wonder egter of al die ander filosofiese wetenskaplikes en wetenskaplike filosowe en teoloë nog hulle filosofiese beskouings so wyd en syd sou verkondig as hulle 'n wyer kennis sou besit, o.a. ook van die biologiese wetenskappe en veral as hulle 'n groot gedeelte van hulle tyd in 'n laboratorium sou deurbring. Dit sou die wêreld waarskynlik ten goede kom as die meeste van ons liewer oor hierdie soort probleme sou swyg en gehoor gee aan die gesegde ,, Skoenmaker bly by jou lees." Die wetenskap is nog maar aan die begin; die onbekende wêreld lê voor en die pad is lank en moeilik. Laat ons dus nie stilstaan om die tyd te verkwis met 'n onvrugbare en nodelose stryd om woorde nie.

,,. . . There's magic all around us,
In rocks and trees and in the minds of men,
Deep hidden springs of magic.
He that strikes
The rock aright, may find them where he will."

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CONCEPTIONS ABOUT NORMALITY IN STRUCTURE AND FUNCTION

BY

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Presidential Address to Section D, read 3rd July, 1944.

It is intended to show that with the progress of knowledge it is becoming more and more difficult to have a clear conception of what constitutes a normal man or animal. No animal ever lives under optimal conditions. No two individuals of the same population living under exactly the same conditions are exactly alike in their hereditary constitution, inborn resistance and vitality. Individuals of the same species resemble one another more or less closely in structure and in their physiological properties, and this tendency of biological characters towards a standard type is an expression of the approximate harmony between the organism and the environment. The resemblance is greatest between the animals born of the same parents at the same time. Even when relationships between individual animals are of the closest type, they show differences from one to the other. It is, therefore, far from easy to state what is the normal of any given character. The organism and its environment must be viewed as a whole. Probably there is no such thing in nature as an absolutely perfect biological equilibrium— a condition in which no species is either decreasing or increasing, their relative numbers remaining constant. At several times during the past, whole faunas and floras have become extinct and have been replaced by new ones, but these natural changes have been exceedingly slow. Unfortunately the environmental changes wrought by man are often much more rapid. In a few decades vast forests have been destroyed, thousands of square miles of grass lands have been brought under cultivation, water has been carried into arid regions for irrigation, swamps and lakes have been drained, immense herds of mammals have been destroyed and various other species (cattle, sheep) have been introduced. In many other ways the balance has been disturbed. Such rapid transformations of the environment have introduced many complex problems which, in the Union of South Africa, as a result of its climatic conditions, have become greatly exaggerated.

In this discussion it will be possible to consider structure and function in the higher animals only, and in order to avoid many of the involved phenomena of life, an analysis of the mental aspect will not be attempted.

The question of what is normal in human thought, in emotional reactions and in general behaviour is associated with the most complicated organ known to exist, namely, the human brain of which the cerebral cortex is the master tissue. Consideration of these problems must be left to specialists devoting their efforts to the particular knowledge related to the mind. It is, therefore, proposed to discuss the physical and the physiological and not to follow the mental aspects.

In the higher animals a greater stability in the face of environmental changes has been accomplished by the development of a heat-regulating mechanism, so that, provided sufficient food is available, the temperature of the body is maintained at a fairly constant level. In the higher forms of life a complex digestive system has enabled the organism to utilise many different kinds of food, while the storage of excess as reserve materially provides for a constant supply of food, even when it is temporarily wanting in the environment.

By the lay mind a normal animal is often confused with a healthy one. An organism is healthy when not deformed, when it is in reasonable harmony with the influences (Reizungen) of the outer world and capable of maintaining and preserving itself. Health is a condition in which all organs function in sufficient harmonious completeness that the preservation of the whole is ensured. In the normal development of the body many cells may suffer damage and the normal ideal may be lost as a result of outside influences, yet the outward manifestations of health may be maintained.

There are several methods of decreasing the amount of hepatic tissue (pressure atrophy as a result of many parasites; congenital cirrhosis, neoplasms, etc.), yet, regardless of how it has been decreased, the functions of the liver persist in an apparently healthy manner, even with relatively small amounts of hepatic tissue. It is stated that it requires less than 20 per cent. of the normal amount of this organ to maintain its functions.

The organism under certain conditions (sheep and cattle free of protozoal parasites) may, after some time, adapt itself completely to the entire loss of splenic tissue (by splenectomy). Often at abattoirs kidney cysts and cystic kidneys are encountered with extensive atrophy of the renal tissue, yet such animals are slaughtered in a healthy condition. These animals may appear perfectly healthy, but under such conditions are not normal.

There are so many factors influencing or controlling normality that it would appear to be appropriate to stress these in the course of this discussion. Anybody who has been associated with morphological studies knows how extremely difficult it is in borderline cases to define where the normal merges into the pathological. In the course of this address it will become

apparent that the normal may vary within very wide morphological and physiological limits depending on species, race, age, sex, hereditary potentialities and environmental (climate and food) stimuli. Variations in the following may be significant:—The number of erythrocytes and of leucocytes in the circulation, and the weight, size and shape of the heart of animals kept under different conditions (e.g. exercise); the volume of the spleen in different functional states; the lymphatic system and amount of adipose tissue in relation to various nutritional states; the significance of the organelles and secretions in the liver during the diurnal cycle; the function and interaction of the various endocrine hormones in the normal organism; different degrees of resistance or susceptibility which depend in some measure upon the hereditary constitution, etc., etc.

Methods used to Study Morphology and Function.

Many different techniques continue to be explored to study morphology and function of cells, tissues and organs. It will, however, only be possible to refer briefly to some of the more important ones. First and foremost are the usual cytological and histological methods by means of which tissues are fixed, hardened, sectioned and then stained by various dyes, many of which have specific affinities for the different tissues. Sternal puncture and supravital methods of staining have given valuable information in haematological studies. The injection of certain dyes intravenously into the living animal has illustrated that pigment granules become " engulfed " (" speicher ") by certain cell groups in the body and by this means the significance and function of the reticulo-endothelial system have been established. Extirpation of parts or whole organs (liver, spleen, endocrines, sexual organs, etc.) has materially added to our knowledge. Many of the most important additions to the knowledge of biological functions have resulted from scientific observations of pathological variations from the normal. The functions of cells or tissues in organs injured or partly destroyed become so exaggerated that a clearer picture was presented. Extensive destruction of the red cells resulted in a better understanding of pigment metabolism in the normal and of the structure and topography of the finer bile ducts of the liver. Certain diseases of the endocrines, etc., have unravelled many of the mysteries of these organs. In pernicious anaemia of the human subject the presence of the anti-anaemic factor in the liver was demonstrated, and the potency of the liver tissue in the restoration of haemoglobin. By means of studies of locomotor ataxia or infantile paralysis or disturbances at various levels of the nervous system much progress was made in the understanding of the functions of the spinal cord. Much information of the part played by calcium, phosphorus, the trace elements (copper, cobalt), etc., in the healthy animal was gained by a study of the deficiencies which they cause in animals. Investigation of

the changes in structure and function brought about by the deficiencies of the different vitamins in the animal resulted in an understanding of the significant part they play in the normal individual. Finally reference must be made to the knowledge gained and advances made by the study of the culture of tissues and organs. This much involved and delicate technique is rather difficult to apply in most laboratories on account of the lack of proper facilities and trained staff.

The science of non-living matter has made immense progress while that of living animals remains in a somewhat rudimentary state. The slow advance of biology is due to the intricacies of life. It has been stated that we cannot understand the living animal by exclusively studying the dead body. The tissues of the dead have been deprived of their circulatory blood and of their functions. In order to apprehend this inner world as it is, it has been maintained that more delicate techniques than those of anatomy and histology are indispensable. Structure should be studied both from microscopical sections of dead tissues more or less modified by fixatives and dyes and from living tissues while functioning. More use is being made of tissue culture by means of which different types of cells bred in flasks can be studied. The cultivation of cells from the animal body under artificial conditions is certainly the most important new biological method which has come into use during this century. The Rockefeller strain of fibroblasts isolated from the embryonic heart of the chick in 1911 is still being propagated. Each cell type has its own inherent properties characterised by the cells' mode of locomotion, their way of associating with one another, the rate of their growth, their response to various chemicals, the food they require and the substances they secrete. Between the liquids composing the organic medium and the world of tissues and organs there are perpetual chemical exchanges. By the perfusion of organs it has been made possible to dissect the body into living parts and these parts adapt in vitro their morphological and functional activities to the conditions of the medium. The development of artificial perfusion fluids has rendered possible the experimental analysis of the relations between organs and medium. These techniques open to experimental investigation a so far hidden field. The culture of organs has provided a means of determining the conditions of nutrition of each part of the body. It may assist in understanding how the organs form the organism and how the organism grows, ages, heals its wounds, resists disease and adapts itself with marvellous ease to changing environment.

The impression should, however, not be created that histologic and cytologic studies have been without value or that such studies may not be a profitable method of obtaining new facts in regard to cells, tissues and organs. As a matter of fact probably none of the usual methods of investigation and few that offer more fruitful results, are being used less at present than

cytologic research. The main drawback appears to have been that cytologists have not employed standard and controlled physiological procedures.

Brief Consideration of the Study of Normality in Some of the Organs and Systems of the Animal Body.

The structure and function of a limited number of organs will be considered to illustrate how difficult it is to standardise normality unless the living organism is studied in relation to the many influences which continually "bombard" it. Evidence will be made available to show how limited and vague our information still is about the true function of many of the cells and tissues.

1. *Blood and Blood-forming Organs.*

Apart from the difficulties arising out of the nomenclature of the various cells of the blood where terms are applied to either emphasize the function or their developmental origin, confusion is also due to the method of approach. In some instances the observations are made on dead cells in fixed and stained smears while others devote themselves to the study of supravitally stained cells. The number of every kind of blood cell is delicately balanced, and changes beyond a fairly definite variation may have important functional significance. In all experiments the results must show a good deal of apparently arbitrary variation, depending on the individual animals used. Hence the importance of proper controls and the decision as to what constitutes a significant result cannot be overestimated. The error of observation which is usually slight in the exact sciences is often great in biology on account of the variability introduced by the use of varying individuals. Caution is especially necessary in drawing conclusions from a limited number of experiments as to whether the results obtained differ from those of a control series or not.

It is common practice to speak of averages, e.g., we can say that the average number of red cells per cubic mm. of blood in a given community of men is 5·2 million. Such a method although commonly used is unsatisfactory, because it does not tell us how great or how frequent are the departures from the mean, so that we should have no means of knowing in the example quoted whether 4·5 million was within the normal range. The percentage volume of red cells in the jugular blood is low in stabled horses, known not to have done any work for a long time, whereas hard working animals have a high percentage volume for jugular blood. It has actually been stated that race horses in full training may have a percentage volume almost twice as high as stabled animals. Apparently moderate periods of starvation and thirst do not seem to influence the percentage volume to any appreciable extent for any length of time. Variations also occur in the percentage volume of the

same animal on different days and are due to factors which have so far not been controlled. Racial differences apart from climate appear to have negligible influences, whereas altitude appears to have a definite lasting effect on the red cells. From the above it will be evident that the number of erythrocytes per c.mm. seems to differ with the physiological state of the animal and caution is, therefore, necessary not to judge low counts as conditions of anaemia, especially in the horse, where morphological changes of the erythrocyte are slight even in advanced anaemia.

When it comes to a consideration of the white cells of the blood it will be found that physiological leucocytosis (increase in leucocytes) may probably be caused by many factors—exercise, mental exertion, shock, etc., and here it is even more difficult to arrive at normal standards. In the spleens of persons dying instantly following trauma and not infrequently in cases of violent death large numbers of eosinophiles were found in the spleen and we appear to be at a loss to account for the mechanism of the mobilisation of these cells. It must be added that in these cases the possible causes for this eosinophilia such as dermatitis or allergic conditions were absent. In several instances these cells were also observed in the lymph nodes and thymus and their significance in these conditions is at present not understood. An analysis offered by comparative pathology might prove fruitful.

Very little is known of the activities which the lymphocyte carry out in the normal animal. The question whether lymphocytes can give rise to other cell types is one of the fundamental problems of morphologic haematology. There are at present extreme differences of opinion. Marked division of opinion also exists in respect of the building centres of these lymphocytes in the secondary nodules of the lymphatic tissue. Some have opposed the usual doctrine (that the secondary nodules or germ centres are the exclusive sites of the production of lymphocytes) and they are inclined to regard them as "reaction centres" being impressed by their response to bacterial reaction and toxic stimuli. It is apparently difficult to reach a decision because these secondary nodules or germ centres are not always functioning at the same rate. The lymphatic system was studied in guinea pigs reared in a bacteria-free environment. The lymphatic tissue reached good development at sixty days on winter food, summer food and feed available during the transition period. It was found that the absence of bacteria did not influence the vitality of the animal in a positive or negative way. The bacteria-free animals, however, in their growth showed a slight retardation as regards body weight, whereas the retardation in the development of the organs was more marked. In the bacteria-free group the lymphatic system showed retardation in development and was most marked in the mesenteric, the cervical and bronchial lymph glands as

well as in the lymphatic tissue of the intestines. It would thus appear as if the ordinary non-pathogenic bacteria in guinea pigs seem to influence them advantageously. These studies would seem to support the view that the function of the lymphocytes is to combat bacteria and bacterial toxins, and that the secondary nodules should be regarded as reaction centres. In a study of renal injury in dogs accompanied by lymphatic atrophy, it is believed that the search for a lymphocytic maturation factor in the renal cortex seems to be warranted, i.e., that consideration should be given to a hormonal activity by the kidney. In a study on the adrenals in its relation to the susceptibility to a transplanted leucaemia of rats, it has been stated that it is not unlikely that the activity of the lymphoid tissue can be influenced by hormones.

In the pathological studies of East Coast Fever it would appear as if the lymphatic tissue is adversely affected. Much is still to be learned how this is brought about. Is the cachexia in the final stages of this acute and rapidly developing disease and the death associated with an interference or loss of a vital function of the lymphocyte in the animal body? It is remarkable how consistently the infiltration of lymphocytes around the walls of blood vessels in the brain is manifested in many forms of encephalitis caused by viruses. Is the function of the lymphocyte in these virus diseases of the nature of a defence mechanism? Will pathological studies throw further light on the normal function of the lymphocyte, still one of the mysterious cells of the living body?

The spleen is intimately concerned with blood destruction and further has a controllable reservoir of blood, aiding the circulation in volume changes of various kinds. The volume of the spleen was estimated in an animal in full health and exercising his normal functions. Several rather ingenious operations on the spleen, e.g., making the spleen extracutaneous, were undertaken in the study of the alterations in the volume of the normal spleen and to explain their significance. It has been stated that the rapid disgorgement of the blood of the spleen in the dog may be influenced by the following: asphyxia, carbon monoxide poisoning, exercise, haemorrhage and even emotion. In the dog the spleen contracts to about one half to one third of its size during exercise and to an even smaller volume on death or severe haemorrhage. In its role in buffering mechanically the vascular system against sudden emergencies, how is the marked variation in the size of the spleen at autopsy to be interpreted, and when does an increased volume assume a pathological state (e.g. a tumor splenis)? The other probable functions in relation to digestion and metabolism are still sub-judice. Splenectomy has been undertaken to study some of the functions of the spleen. It was shown that in animals, not carriers of protozoal parasites, the organism can adapt itself and after a time appear normal. It would appear that human patients

deprived of their spleen may develop malarial relapses, in some instances ending fatally. Splenectomy carried out in various animals such as apes, horses, cattle, sheep, goats, pigs, dogs, some South African antelopes, rats, etc., has brought about relapses of such diseases as Plasmodium infection, piroplasmosis, anaplasmosis, Spirochaeta and Bartonella infections, etc., and in many cases ending fatally. By means of this technique the presence of anaplasma in the Merino was for the first time identified and studied in South Africa. In this species infection occurs in the normal animal without any significant manifestations of ill health. It would appear that the spleen plays a part in the acquisition and maintenance of immunity in some of the protozoal diseases of man and animals, but, unfortunately, very little information is available about the precise function exercised by the spleen. It may be interesting to add that in bovines in which relapses of piroplasmosis were caused by splenectomy and which recovered, the liver revealed foci of tissue resembling that of the spleen in structure and function. Nothing of a similar nature has so far been recorded, and the significance of this new tissue in the liver is at present not properly understood.

2. *The Liver.*

The liver is situated in a strategic position between the great area of intestinal absorption, supplemented by the largest mass of R.E. tissue (the spleen) in the body, and the heart pumping blood to the entire organism. The vital importance of this organ to the body lies in the synthesis of many food products, as well as in the excretion of bile pigments and other waste products into the gut. As a storehouse it accumulates glycogen, amino-acids, fat, etc., and has an effective physiological reserve. Large portions can be destroyed without interfering with the performance of its functions. Removal of large parts of the liver is followed by rapid growth of the remaining portion, the previous size being regained within a comparatively short time. No other mammalian organ has this remarkable restorative capacity. In the white rat when 70 per cent. of the liver is removed, restoration is so rapid that after the 14th day the previous size is actually exceeded. When the whole of the right side is grossly disorganised by disease (atrophy of the right lobe of old horses) a general overgrowth of the left may compensate for it. Complete removal of the liver in the dog has added considerable knowledge about the part played by the liver in pigment and carbohydrate metabolism. Differences in the size and colour of the liver must be carefully interpreted at autopsy. The liver in the fasting animal appears smaller than is usually considered normal and lacks somewhat its characteristic colour. After fasting for a few days a characteristic fatty appearance develops in many species. The liver of the digesting animal, while affected somewhat differently by various foodstuffs,

appears larger than the liver of the fasting animal. Comparing the liver of an animal of a species that hibernates, it will be seen that the digesting state, usually regarded as normal, differs from the hibernating state; in the latter a most extreme fatty condition is evidenced. In the diurnal cycle it is stated that there is a marked change in the quantity of some of the constituents of the liver in relation to the digestive cycle (the deposition of glycogen and in the secretion of the bile components). The greatest amount of glycogen is apparently present in the liver during the night, whereas the greatest amount of bile acid material is secreted during the afternoon. The most conspicuous feature of the normal cytology of the liver is the zonation in the lobule and the changes in the form of the cell organelles and the quantity of the substances stored and secreted in relation to alimentation. There appear to be two important environmental factors which influence zonal prominence, one is the greater supply of oxygen in the periphery of the lobule and the other is the greater supply of the foodstuffs by the way the hepatic artery dispersing itself in the interstitial tissue of the liver lobules. The heavier mitochondria and Golgi substance and the larger amount of glycogen and bile acids would all appear to be manifestations of the high activity of the peripheral cells. The fat deposited in the hepatic lobule presents various appearances and it is not possible at present to state how much of the microscopically demonstrable fat is part of the fat ingested in the previous meal or fat mobilised from the other fat depots in the body. On a well-balanced diet in dogs the fat content of the normal liver appears to be fairly constant, viz. about 2·5 per cent., whereas it can be increased to 50 per cent. by feeding a fatty diet for a sufficient length of time.

In recent researches on the function of the liver, its defence mechanism against chloroform was stressed. It was found that a protein depleted dog was extremely susceptible to chloroform injury, whereas a single large protein feed protects the protein depleted dog from an otherwise fatal chloroform anaesthesia. Methionine (amino acid) given before chloroform anaesthesia is as effective in protecting the protein depleted dog as a large protein feed. A mobilisation of copper in the liver of the sheep in certain grazing areas in South Africa produces an extensive haemolysis in a disease known as enzootic icterus. It is extremely difficult, however, to produce copper poisoning in the sheep even by feeding large doses over a considerable time. Does a function of the liver become impaired by some other unknown factor in enzootic icterus in these areas so that the liver becomes more vulnerable to copper poisoning? What is its relation to copper metabolism?

3. *The Lung.*

The problem of the nature of the alveolar (air sacs) lining of the lung was discussed at a round table conference of the

American Association of Anatomists, but no definite conclusion was reached. In certain pathological conditions the walls change so that the alveoli appear to be lined with a sheet of cuboidal cells, or even columnar cells, which have all the characteristics of true epithelium. From these swollen and altered cells papillomatous growths may develop and project into the lumina (adenomatosis of the lungs of sheep). Will these pathological studies eventually be able to explain the true nature of the normal lining of these air sasc?

4. *The Endocrines.*

Some remarkable information has within recent years come to light from the numerous studies on the endocrines and the many facts established provide a purely natural basis for some of the most mysterious performances in the living body. The sex hormones modify the attitude and behaviour of many or all higher animals. The castrated animal soon loses part of what may be called the usual or normal attitude towards the opposite sex. It has been said that one of the hormones—prolactin—is capable of producing broodiness in birds and the maternal instinct in mammals. Much progress has been made during the last 20 years in experimental endo-crinology, particularly as regards the mechanisms governing mammalian reproduction and the mechanism which controls lactation in farm animals. In a consideration of the function of the anterior pituitary, reference was made to a specific anterior pituitary lactogenic hormone, initiating and maintaining milk secretion, and also to another factor or complex of factors having an influence on the fat metabolism of the mammary gland.

5. *Other Organs.*

Attention has been drawn to the lack of accurate knowledge about the function of the sweat glands in the skins of bovines. The statement has been made that Zebus have retained and European cattle have practically lost their ability to sweat. Instead of sweating cattle eliminate water vapour through their lungs and in that way the regulation of heat is assisted. As the temperature rises the animals respire at increasing rates and it is believed that this rate of increase is much greater in European breeds.

In certain areas of Great Britain, Australia, South Africa, etc., a nervous disorder occurs in newborn and young lambs born from apparently normal ewes. Different breeds may be affected and the incidence on affected farms may be as high as 90 per cent. The pathology is characterised by diffuse symmetrical changes (demyelination) in the brain (cerebrum). Apparently a disturbance of copper metabolism in the pregnant ewe is responsible. Success has attended the prevention of this condition by feeding copper to pregnant ewes, but the exact role copper plays is as yet not understood.

Unfortunately time does not permit to refer to equally interesting studies in the remaining tissues and organs of the animal body.

PHYSIOLOGICAL LONGEVITY.

The problem of physiological or normal longevity deserves a brief reference. How long may a normal animal expect to live under optimal environmental conditions, dying from senescence? The following periods have been established, e.g., it is believed that the mouse is old at 2 years, the rat at 3, dog at 10-12, the horse at 20 and the human at 70. It is possible that any individual out of an animal population bred under optimal conditions (climate, food and protected from parasites and accidents) and selected from a thoroughly healthy and genetically homogeneous stock will die a physiological death. Various types of cell injury due to old age have been recorded (changes in the nuclei, excessive pigmentation, atrophy of the cells, periportal infiltrations in the liver, etc.). It is stated that there are definite histological differences between the liver of young and middle aged mice on the one hand and senile mice on the other. It is believed that in ageing a progressive differentiation occurs which ultimately injures the cells of the body. Many of these cells die while others become "differentiated cells" which keep the power to grow, but their power to function, may be diminished or lost. It has been maintained that from these differentiated cells neoplasms arise which account for the high incidence of new growths during later years both in man and animals (wild and domestic). The question of the age of the species from which tissue and organs are collected at autopsy should not be lost sight of in connection with changes encountered in cytological studies.

THE INFLUENCE OF CLIMATE AND BREEDING.

The statement that physiological norms in the tropics differ from those in cooler lands has been seriously criticised. Apparently average readings have often been resorted to without sufficient regard to health, age, sex, diet, nutritional state, etc. In spite of the meagre knowledge of tropical physiology, it is stated that the most effective mechanism of physical heat regulation under warm conditions, namely sweating, has a tendency to produce rather deleterious effects on blood chemistry and on the tone of internal organs with the result of lowering resistance to infection. It is, however, held that we have hardly begun to learn the adaptive possibilities of higher animals, which will maintain them against progressive deterioration as a result of the influences of climate.

In most classes of stock there are apparently optimum climate conditions under which they develop and reproduce within the limits of their inherent capacity. In the Gulf coast area of the United States of America an ideal animal is considered one that can endure the intense heat and high atmos-

pheric humidity of summer, resist insect pests and diseases and grow rapidly and produce a desirable beef carcass on grass. Because such animal was not available in the Texas State, Brahman cattle, indigenous to India, were introduced to synthesize a strain by crossing with Shorthorn and Hereford. It is stated that a suitable type $\frac{3}{8}$ Brahman and $\frac{5}{8}$ European has been developed. In certain states of the United States of America it is held that climate influences the production of dairy cows, fed on a high plane, more directly as shown in the determination of the butterfat. Unfortunately climate is a highly complex state including such factors as temperature, humidity, atmospheric pressure, wind velocities, amount of light, etc., and it is extremely difficult to determine their effects separately on the living organism. An index figure of 100 was assigned for the ability of an animal to maintain normal body temperature of 101·5°F when exposed to the sun with a shade temperature of 90°F. When this was applied to various breeds the following standards were arrived at:— Purebred Zebu 93; Jersey 86; Half Afrikander 83; Grade Herefords 73 and Pure Aberdeen Angus only 56. Apparently the Jersey appears to be the only European breed to be more nearly comparable with the Tropical types.

Since 1925 macro-morphological, biochemical, environmental and to a lesser extent histological studies have been undertaken in South Africa to investigate the environmental forces upon growth, development, reproduction and production of successive grades of indigenous and exogenous breeds of cattle. The results seem to indicate that the indigenous grades (Afrikanders) have maintained their conformation for several generations, but that comparable groups of exogenous breeds (Red Polls, Fries) have failed to do so. These studies are being continued, but greater consideration will have to be given to a more detailed cytological investigation of the organs and tissues, especially those more vitally concerned (viz., the blood, skin, the digestive system, musculature, endocrines, etc.) in animals of different ages, sex, generations, etc. This is considered essential if it is desired to ascertain to what extent deviation from normal conformation, growth and development occurs.

Scientific breeding has become a major branch of science, taking its place beside chemistry and medicine. The field of breeding and genetics has become vast and is dependent on the progress in basic research. It has been suggested that the more superficial standards of breeding (e.g. aesthetic show points, pedigrees) should be replaced by better ones. Ideals change from time to time for the same class of stock and from one locality to another. Productiveness, fertility, vigour, etc. are characters of profound biological significance affected by many things in the "make-up" and the environment of the animal. They are certainly the result of many genetic factors closely interacting and this makes the problem of analysis so extremely difficult. For instance, in the United States of America it was

possible by selective breeding to establish strains of rats which differed significantly in their efficiency of feed utilisation. The experiment showed that efficiency of feed utilisation is effected by heredity and can be significantly changed by the application of genetic principles. It should, however, be stressed that a grading-up policy cannot be confined to genetic improvement alone. Consideration should at the same time be given to environmental forces, e.g. poor soil, inadequate rainfall, sparse vegetation, in which the greater part of South Africa for the greater part of the year is deficient and in which the disease complex is successfully controlled.

The Problem of Immunity and the Carriers of Disease in what are regarded as Normal Individuals.

Some of the higher animals are subject to certain diseases, against which others are immune. We are ignorant of the nature of natural immunity, although it would appear to be dependent on some properties of ancestral origin combined with other properties acquired in the course of development. Many studies on the mechanism of acquired immunity have been undertaken and successful methods of preventive and curative immunisation have been established for a number of diseases of man and animals. We are, however, not in a position to state by which tissues in the body resistance is established and maintained, especially in the more lasting immunities (e.g. smallpox), and whether the virus in such cases has completely died out in the body. It is also not known at what stage after the reaction the individual returns to normal. Of great epidemiological significance is the fact that in some of the virus diseases, apparently normal animals and plants may harbour the virus within their cells without showing any evidence of disease (latent virus infections). Such "carriers" may be responsible for initiating outbreaks directly or indirectly in susceptibles. A normal course of events is for budgerigar nestlings in aviaries in California to develop symptomless infection with psittacosis virus. Fowls affected with fowl pox virus continue to harbour the virus for long periods and in laryngo-tracheitis disease of fowls the virus may be found in the trachea for as long as two years. It is stated that the virus of infectious anaemia of equines has persisted in apparently normal animals for periods as long as 14 years. This disease was identified in horses in the Union in 1913 during the preparation of horsesickness serum. It is quite possible that this infection was introduced from outside by so-called normal horses, because this disease has not established itself here whereas in many parts of America and Europe it remains endemic. The virus of foot and mouth disease was detected in the urine of hyperimmune cattle 246 days after infection by a method involving adsorption of virus on charcoal. In South Africa it has been shown that T. equiperdum (dourine) can be harboured in apparently normal mares for several years. These mares were in some instances able to transmit the disease

by coitus. Trypanosomes exist as apparently harmless commensals in the blood of the larger wild ruminants (antelope). A tolerance between the game animal and the parasite developed so that eventually host and parasite existed on terms of harmony. Such carriers play a rôle in the maintenance and spread of infection in man and domestic animals (nagana, sleeping sickness). Apparently normal warthogs as carriers of swine fever were responsible for initiating the extensive outbreaks in domestic pigs in the Union in 1933-1935. The part played by the normal Wildebeest in transmitting the virus of snotsiekte to bovines is well known in South Africa. The presence of a very virulent virus capable of producing a paralysis in mice has been described in America. The almost universal presence of this virus in the intestines of apparently normal mice of a certain age was demonstrated. Its uniform pathogenicity for mice by the intracerebral test was proved, as well as the persistence of the carrièr state for long periods of the host's life. It is possible that the occurrence of spontaneous clinically apparent disease occurs in only one among thousands of animals.

A small quantity of virus persisting in the tissues of a recovered animal may be difficult to demonstrate. It may only be intermittently present in a small proportion of recovered animals, it may be neutralised by the antibodies present, or it may be due to the fact that no suitable technique has as yet been evolved to recover the virus. But given a certain combination of conditions in nature, e.g. weather, presence of biting insects in some instances, and appropriate hosts, etc., an outbreak of the disease may be initiated. If one or more factors are absent the disease may lie dormant and only appear if the balance of nature is altered. This " carrier state of viruses " in apparently normal animals is of great significance, especially in the control of infectious diseases such as psittacosis, swine fever, possibly also foot and mouth disease, rabies, equine encephalomyelitis (which is also transmissible to the human) equine infectious anaemia, etc. In many infectious diseases the recovered " normal " animal is naturally looked upon with a great deal of suspicion, especially in those cases where it is impossible to show how the infecting agent maintains itself in the interim between epidemics or seasonal outbreaks. Southern Africa had been free from foot and mouth disease since 1895 until it was suddenly introduced into Southern Rhodesia in 1931. Since then there have been several recrudescences with intervals of several years, especially in those territories where the virulent virus was used widely in the immunisation of all bovines. During these intermissions the authorities of the respective territories were satisfied that the disease was no longer present in cattle, in spite of the fact that since 1931 foot and mouth disease has been of such a mild nature that it could only be clinically detected in a herd with the greatest difficulty. The question arises as to how this virus is being propagated and maintained during

these intervals of freedom from disease. It is believed that the virulent virus by its extensive use has been transmitted from bovine to game and that in certain species it is being propagated without any visible manifestations. It may be added that the virulent virus has been recovered from Kudu in Southern Rhodesia and there has been suspicion of the disease in other species of game as revealed by some of the specimens submitted for investigation. In order to prevent introduction of the virus into the Union, import regulations have been promulgated to prevent the introduction of the species in which the virus may be carried. The lay mind often considers these regulations as unduly harsh and even without any foundation.

Finally it may be mentioned that arrangements have been made for a series of papers in Section D to consider further aspects of the problem of normality.

SUMMARY.

It has become apparent that it is practically impossible to define normality, unless at the same time we consider the organism in its relation to environment (particularly food and climate), and unless due consideration is given to species, race, age, sex, nutritional state (diurnal cycle), and hereditary influences. Animals may appear healthy yet some of their internal organs may not be normal. Reference is made to normality within wide physiological limits, and the difficulty experienced in deciding where the normal merges into the pathological.

The various techniques to study morphology and function are briefly referred to, as well as the important rôle of pathological studies and the culture of living organs and tissues.

Variations in the number of red cells, and leucocytes per cubic mm. of blood should be carefully considered before a diagnosis of a pathological state is arrived at. The function of the lymphocyte and the " germ centre " of the lymph gland is not properly understood, and it is quite feasible that further pathological investigations may assist to unravel these problems. By means of splenectomy much knowledge has been added to explain some of the functions of the spleen. In view of its variations in volume within physiological limits, careful consideration should be given, before any extensive increase in volume is diagnosed as a pathological state. The rôle of the spleen in probably initiating and maintaining resistance against certain protozoal diseases is briefly mentioned.

Data in respect of the structure and function of the liver are referred to, e.g., its remarkable restorative powers; destruction of large portions may not interfere with its functions; complete extirpation of the liver has led to a better understanding of its part in pigment and carbohydrate metabolism; differences in size and colour of the liver in the " digesting " and " fasting " animal; changes in the liver cells during the

diurnal cycle; its defence mechanism against chloroform anaesthesia in the dog on certain protein diets; the probable greater vulnerability of the liver in certain nutritional states to copper poisoning.

Brief reference is made to the differences of opinion in respect of the true nature of the structure of the lining of the lung (air sacs). It is mentioned that the endocrines are responsible for some of the mysterious performances and adjustments of the living body.

Scientific breeding should become more indispensable for making agriculture more efficient. The application of genetic principles should replace the more superficial standards of breeding. The meagre knowledge of tropical physiology is mentioned and an indication given of the breeding possibilities of crosses between cattle indigenous to India and certain European breeds under tropical conditions. Reference is made to the environmental forces in respect of successive grades of indigenous and exogenous breeds of cattle under certain South African conditions.

The problem of natural immunity in the normal animal is mentioned. At present it is not known what part the different tissues play in initiating and maintaining an acquired immunity. Normal animals may harbour some infection within their cells or tissues, without any evidence of disease (latent carriers). The important rôle of such carriers in initiating under favourable conditions new outbreaks of disease is stressed, as well as the action necessary to prevent the possible introduction of infection by apparently normal animals into countries where these diseases do not occur.

Conclusions.

A lack of accurate information exists in respect of our knowledge of normal structure and function of the cells, tissues, and organs of the living body. This is bound up with reactions involving the study of many branches of science. It has become pre-eminently clear that the living organism cannot be treated as a test tube in which an endeavour is made to study these reactions without due regard to structural variations and changes that may have been produced. If we, in the study of the problems of nutrition in animals by means of feeding tests, only consider intake, energy produced and output, it must be clearly realised that the digestive tract (including the liver) is at the same time involved in a complex set of reactions (not yet properly understood). There may be important physiological and structural changes in the cells of one or more tissues brought about during the process of intake, digestion, absorption, excretion, etc. Who, for instance, would consider phosphorus and calcium feeding tests by only recording weights, etc., without due regard to the cytological changes that may occur in the skeleton and probably also in some of the other organs. The Medical or Veterinary Worker with the basic knowledge of physiology, histology, pathology, medicine, etc., must establish

close collaboration with the chemist, biochemist and biophysicist. How can long range breeding experiments, particularly under the adverse conditions in Southern Africa, and especially in relation to nutrition, and bioclimatology, be undertaken without provision being made for cytological and physiological studies, in order to ascertain what constitutes the normal and in what ways deviation from the normal has occurred. The apparently normal animal in such tests may show cytological changes in one or more organs, deviating to a lesser or greater extent from the normal.

The live stock breeder is not nearly as advanced as the plant breeder in applying genetics to his problems. Most of the excellent breeds of fairly uniform cattle (in the United States of America and Europe) are not the result of the application of the knowledge of genetics, but of long continued empirical selection of the desired type. It must be remembered that breeding is only a part of the whole biology of the animal organism.

In this address it was stressed that there are innumerable examples where the so-called normal merges into the abnormal, the line of demarcation frequently assuming a very ill-defined character. Yet there are some who are of the opinion that the study of a "normal" animal, especially as regards breeding and nutrition, should be entrusted to one group of investigators and the study of the "deviation" from the normal to another. Unfortunately some of those who frequently have to advise on and guide research problems, have never undertaken any form of basic research themselves, and yet in many instances it is they who have the final decision in the planning of research schemes, providing suitable facilities for study, and the selection of staff. Long range experiments involve many branches of science and they will, therefore, not be an economic proposition, unless such experiments are properly co-ordinated, and this should be done by those well versed in research, and who have the necessary training and experience.

In view of these considerations it will be in the interest of the State if all the above studies relating to stock can be vested in a Division of Animal Health, on the same lines as exist in the Department of Public Health or the Bureau of Animal Industry in America. There are only a small number of scientific workers in the Union interested in morphological and physiological studies and it is essential that more frequent consultation should be established. The value of comparative studies has frequently been referred to and it will be in the interests of the State if a closer collaboration between medical and veterinary institutes and faculties in the Union can be brought about.

The issues raised should receive consideration in any post-war replanning scheme, especially where the health of man and

animal is concerned. The very close dependence of human nutrition on animal nutrition and health is a matter of the greatest national importance, and one which demands far greater emphasis and consideration than it has received so far in South Africa. It should be remembered that such animal products as milk and meat are valued amongst the most essential protective foods in the diet of man.

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SOCIAL ANTHROPOLOGY AS A STUDY OF CULTURE CONTACTS

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Presidential Address to Section E, read 3rd July, 1944.

My aim in this paper is to discuss the approach of Social Anthropology to contact between societies with different cultures. I here use the word culture in its widest sense to include the material side of social development as well as the organisations, behaviour and beliefs of men as members of society.

The process of contact or acculturation is not limited to our own times; the history of societal evolution is largely the history of groups migrating through famine, persecution, the desire for adventure, economic gain, or political prestige; and influencing, and being influenced by, peoples whom they met on the way or in whose countries they settled.

The scientific analysis of this process in prehistoric times is undertaken by the Archæologist and Physical Anthropologist, and to them we are indebted for a time perspective of the lichen growth of human civilisation on the rocks of ages. Bones and tools are, however, only clues in a drama which can never be fully understood, once the human actors are dead. Thus the beads of Zimbabwe indicate a time link with Asia, but we do not know by whom the beads were worn, nor the values attached to them.

Apart from the Archæologists' contribution, historical documents describe culture contact among literate people throughout the centuries. We read in the Vedas, composed probably as far back as 1200 B.C., of waves of Aryans influencing the Dasyas, earlier occupants of India; and old Chinese texts record migrations and contacts dating from, roughly, 2300 B.C. The contact and struggles between tribes and nations provide the material for modern historians, and are described by members of one school as a series of accidents best depicted in biographies; another school, interpreting events by the rigid formula of economic determinism, denies the influence of any individuals on social trends. Other historians fluctuate between these extremes, and some link up closely with those sociologists who trace the developments of social movements through both group and individual relationships over a period of time.

The Sociologist who deals with contemporary societies finds the contact of cultures an integral part of his subject. The

position is most conspicuous in America, but it is also evident in every country in Europe. In many instances, however, the sociologist's horizon is limited by his own culture, and his conclusions have not been extended to the data of Ethnography. In the develpment of the so-called primitive societies, contact has also been operative. Thus we know that the Bantu-speaking tribes of Africa resulted from Hamitic and Negro intermixture. influenced, as groups of migrants moved southwards, by Arab contacts along the east coast.

No sharp distinction can be drawn between Social Anthropology and Sociology; Sociology is concerned with human social behaviour in all places and at all times, not merely with its manifestation within our own historical milieu. As far as we know, biological needs are the same thoughout the species *Homo Sapiens*, though they are satisfied by diverse institutions. Emphasis on distinction between Social Anthropology and Sociology obscures the fundamental unity of mankind. For convenience it may be necessary to divide the field into a study of preliterate and literate peoples, but it must be borne in mind that an equally valid cleavage could be drawn between people with and without the wheel, or between agriculturalists and industrialists. The distinction is not only arbitrary, but (for political or other motives) may be misinterpreted. The South African scene exemplifies this danger; the preliterate peoples (the Bushmen, Hottentots and Bantu-speaking tribes) are also dark-skinned, and by regarding them as the special subjects of Social Anthropological research, politicians and others have misused anthropological monographs to stress and perpetuate the difference between non-European and European. Descriptions of their analogous customs and beliefs, and analyses of increasing institutional interdependence are rare and relatively recent. The emphasis on a common humanity is frequently ignored.

I have indicated that Archæology, Physical Anthropology, History, Sociology and Social Anthropology all deal to some extent, though from different angles, with contact between culture groups. The delimitation of the scope of each of these "sciences" is in fact artificial. Science cannot be defined by its subject matter, for science is a method not a substance. The method of science, whether applied to inorganic or organic matter, is similar; it consists of accurate description, verification and generalisations. The subject matter of the natural sciences lends itself more easily to the scientific method. But I believe that, as the physicists and chemists have obtained knowledge of the inorganic world, by laborious research, so Sociology, with the aid of Archæology, History and other sciences, will wrest from society, and the individuals within society, general laws relating to the sequence of social events, and be able finally to predict the behaviour of men swept along social channels.

It is necessary to emphasise that contact takes place between peoples of similar, as well as of different, ethnic origin. Before Europeans arrived in Africa or America, the tribes of those countries were borrowing from and influencing each other. Similar ethnic origin did not engender similar civilisation or culture, and it is interesting to notice that ethnic similarity or difference is but one of many factors affecting the receptivity of people to innovations. Bantu-speaking tribes prior to European arrival maintained distinctive tribal customs despite intertribal contact; the power which is breaking down tribalism is the economic pressure backed by force exerted by technically more advanced, ethnically self-conscious Europeans. The type of contact confronting the modern anthropological field-worker in Africa is pre-eminently that of Western European industrial civilisation imposed on primitive peasants. This situation is not restricted to South Africa, but is evident over the whole world.

The social anthropologist is no longer able to study isolated communities untouched by industrial civilisation. The people of the Andaman Islands, who, as described by Radcliffe Brown, were without the knowledge of fire making, are now in the range of Japanese-American warfare; the primitive Semang and Sakai in the Malayan peninsula are less than two hundred miles from Singapore; American wireless stations have been established in the Arctic region of the Eskimo; the great Trans-Siberian railway and communal farms in Central Asia are manned partly by erstwhile nomadic herdsmen. As communications advance, the peoples of the world are drawn into even closer contact.

The term culture contact gives a somewhat false impression of the situation; two cultures as such do not come into contact. What happens is that a certain number of individuals representing certain interests, and to some extent stereotyped by these interests, introduce new modes of behaviour and belief. The innovations do not act at even pressure; thus in the present situation in South Africa administrators may use more force than traders, yet the traders may exert more marked influence. There is no rigid, co-ordinated line of attack, no united front, but jagged impact of different individuals and groups reacting to social forces of which they are usually unaware.

Culture contact must be seen as a particular stimulus in the process of general social evolution, using the term evolution without any ethical concept of progress, and as roughly synonymous with adaptation. Stimuli to change are both internal and external. Thus necessity to provide for a natural increase in population is an important internal social pressure leading to material innovations and changes in the social structure. Investigations of primitive societies show how precarious was the balance between scarcity and plenty; and no myth is further from the facts than that which describes mankind as starting

in a state of nature characterised by abundance, peace and equality. Societies when isolated from outside influence, tend to perpetuate to levels of adjustment which satisfy the needs for food, sex, protection and belief. But as far as we know, no society has remained completely unchanged for any length of time. Nor can the more slowly changing societies be identified with the simple (i.e. "primitive") and the more rapidly developing with the highly complex (i.e. "civilized"). The complex caste system of the Hindu was one of the most rigid of all known organisations.

Contact between cultures, i.e. stimulus from outside, accelerates the tempo and introduces new types of social adjustment. Within this broad generalisation falls the wide range of particular cases. Stratified Indian society is the result of the impact of different ethnic and occupational groups. In Uganda we find three distinct types of society arising from the interaction of roughly similar ethnic elements: in the kingdom of Ankole along the western borders the strongly Hamitic Bahima established themselves as a ruling class over the predominantly Negro Bahira, whom they regard more or less as serfs; among the Bakitara, the Hamitic invaders still form an aristocracy but in between has emerged a third group, composed of descendants of intermarriage with daughters of the Bahira and now constituting the mass of the Bakitara; among the Baganda the fusion has been complete.

The process of contact is complicated when it takes place between more than two groups simultaneously, as it has in South Africa where the non-Europeans include Bantu, Indians, Coloured and Chinese; and where the Europeans include two opposed national groups, with the Jews isolated as a peculiar unit for political purposes. Contact moreover is never one-sided; every group is influenced by, and influences, the rest.

II

The question now arises, how do the social anthropologists study the wide-spread and varied situations of culture contact. I have not the time in this paper to trace the development of the methods in any detail, but I will briefly survey the main schools of thought in Germany, America and more particularly England. For it is significant that schools of Anthropology tend to have geographical-political affiliations. Whereas the principles of the natural sciences have international currency, those of the social sciences are influenced by the societies and sections of society from which the research workers are drawn, and the opportunities they have for their research. It was no accident but rather political considerations that led the German and American anthropologists to emphasise the historical method, while in England the functionalist approach was most fully developed; students of all three countries, especially in recent years, have stressed the practical importance of Anthropology.

The German colonial empires were smaller and of shorter duration than those of Britain. In the nineteenth century when Anthropology was developing as a science, Germany was occupied in unitying and consolidating her power on the continent; contact with primitive peoples was limited, and knowledge of their mode of living relatively unimportant. The German Anthropologists, Ratzel, Graebner, Ankermann and their followers had the museums as their laboratories and a number of monographs of unequal accuracy and detail as their texts. Using this material they mapped with infinite labour the geographical distribution of material objects and types of social organisation, and, noting striking resemblances between cultures far apart, drew conclusions of wide-spread historical contact. The civilisations of the world assumed a certain order, but it was the order of a vast jigsaw puzzle, lacking the animation of life. It is true that some of the writers, more especially Graebner, recognised in theory the importance of the psychological element —the bearers of culture—but in actual treatises this was passed over and mechanically composed Kultur Kreise were transferred as it were by their own impetus over the globe. The spatial distribution was then translated into a time sequence of man's movements since the palaeolithic period. The interest of the German ethnologists was in the history of culture in general, rather than in the study of culture contacts.

In America the waves of migrants from Europe establishing themselves in the country of the American Indians, practically exterminated these earlier inhabitants before studying them. There were certain exceptions to this general process. For example, the French along the St. Lawrence sought the friendship of the tribes, which, however, were warring between themselves and played off one European power against the other. The first aim was then to reconstruct the rapidly disappearing past, and for this the American anthropologists, fathered by Franz Boas, had recourse to accounts by surviving tribesmen, to early documents and to museum collections. They developed the technique of plotting the distribution of connected traits—material objects, types of social organisation, myths and so on —and then interpreted the distribution in a historical sequence, much as the archaeologist works with the principle of stratification. Unlike the German scholars, the American diffusionists did not attempt to deal with the history of culture throughout the universe; they limited their analysis to the material that concerned them most directly—the material of the New World. The school produced some excellent monographs on early Indian culture and detailed analysis of the spread and adoption of particular artifacts, customs and beliefs. But in the quest for associated traits, the workers tended to overlook the society as composed of individuals, with the result, to quote Murdock, that " they have in a sense isolated their (anthropological) discipline from the main currents of modern (sociological) thought and

made it a sort of antiquarian appendage to the social sciences." Murdock (1937: XIV-XV).

It is perhaps also inevitable that, dealing primarily with relics of disappearing societies, the theoretical contributions of the American workers are mainly on the processes of change—diffusion, parallel development, convergence and so forth—rather than on the social effects. Only a few students went outside America to areas where primitive life remained relatively intact, e.g. New Guinea and Samoa. Recently however, perhaps through independent origin, or contact with other currents of sociological thought, or even through an increasing interest in colonial problems, a number of Americans have turned their attention to the specific situation of culture contact (or as they call it, acculturation), studying how existing tribes or remnants of tribes responded, and are responding, to the stimulus in terms of their general social interests. (Redfield and others, Vol. XXXVIII; Herskovits, 1938; Linton, 1940.) This approach has much in common with that of the younger group of anthropologists trained in London.

In England the analysis of culture contact passed through a roughly analogous cycle. England included among her colonial peoples tribes which were rapidly dying out, tribes which were relatively untouched, and tribes which were being radically transformed through contact with similar ethnic groups and also with civilisations of the East. English anthropologists studied in situ societies of different types and at different stages of contact. The early anthropologists on the continent and particularly in England were influenced by the biological theories of Darwin and Lamarck which lent some support to European control of strange people. Calverton (1931: 5) describes evolution as the "ideological armament" of nineteenth century civilisation. The old evolutionists assumed that similarities in different parts of the world were of independent origin, attributed them to the fundamental identity of the human mind all over the world, and described development in human societies as gradual, uniform and progressive, the European culture being the highest yet attained. But in the hands of radicals, evolution was shown to have different implications; the nineteenth century values were regarded as themselves transitory.

It was in 1911, the year of publication of Graebner's masterly contributions on methods of ethnology, that Dr. W. H. R. Rivers in his famous address to the British Association issued his challenge to the old evolutionary school to which he himself had formerly adhered. On the basis of a scientific expedition to Oceania, Rivers put forward the thesis that the development of culture was primarily the result of the contact and blending of peoples. The writings of Rivers and especially his "History of Melanesian Society," are in many ways the precursors of the modern studies of culture contact. Though interested primarily in social psychology and history, his work in the field

made him aware of the complexity of social structure, and led him to investigate how and why it changed through external stimuli. Unfortunately in his efforts to prove that diffusion was the main source of cultural evolution, he multiplied hypotheses and made wide generalisations which subsequent research in other societies proved untenable. But he called attention to the receptivity of societies and the transformation which innovations underwent in the old milieu.

While Rivers and others including notably Elliot Smith, were analysing historical movements lying under the surface of existent cultures, there arose in London the functionalist school largely under the inspiration of Bronislaw Malinowski. Malinowski, the Conrad of Anthropology, spent nearly two years among the Melanesians and was enabled by his gift of intuition and his powers of observation, to project himself into the life of the picturesque islanders, and to describe their activities, beliefs and emotions in a series of intensive and exceptionally graphic monographs. Largely on the basis of his field work experience, Malinowski elaborated the thesis that each culture consists of interrelated, effectively functioning institutions. He denied the value of discussing material objects, practices or beliefs outside of their particular social or cultural context; he considered that the better a society was understood, the fewer survivals appear to be in it. In criticising the approach of German and American diffusionists, he expressed a distinct anti-historical bias, he claimed that "scientific observation can only be directed at what is; not on what might have been, or has been, even if this had vanished but yesterday," Malinowski (1938, p. XI). Now his approach as he himself stated was worked out with the purpose of describing and analysing one culture, and a culture at that which through age-long historical development had reached a state of well-balanced equilibrium. To Malinowski it was not important that this same Melanesian culture was regarded by Rivers as a result of contact between two or three culture waves.

An approach in some respects similar to Malinowski's was expressed by Radcliffe Brown, who did his research among the primitive Andaman Islanders. His work in South Africa apparently modified his initial arch-functionalism, and led him to note the process of culture contact, but in 1931 he still regarded "any persisting culture as an integrated unity or system in which each element has a definite function in relation to the whole." Radcliffe Brown (1931, 158).

Students of Malinowski and Radcliffe Brown, more especially those who did their fieldwork in Africa, did not find homogeneous, well balanced societies. On the contrary, they were confronted with societies going through revolutionary changes in economic organisation, political directions and religious practices. Schapera was the first of the students to concentrate on the

process of culture contact in Africa and he has provided us with the richest material both on its process and effects.

African tribes that were being studied were neither dying out nor were they regarded as museum pieces. Practical or applied anthropology was required. In particular, the British policy of " Indirect Rule " was based on the potentialities of the indigenous cultures. In 1927 an International Institute of African Languages and Cultures was started with its headquarters in London. In 1932 the council put forward a five-year plan of research directed to a study of the effects on African life of European civilisation. The council emphasised that the object was to formulate a sound basis of fact for dealing with the problems of administrators, missionaries, educationalists, traders and others working among the Africans. Fellowships were given to British, German and French scholars, most of whom attended courses under Professor Malinowski.

The material with which the younger anthropologists worked brought the question of a historical approach again to the fore. While it has become generally accepted that a historical perspective is essential, arguments turn on how this can be obtained. Some students consider it necessary to attempt to reconstruct "a sufficient historical background to form a base-line or zero-point from which to measure changes which have taken place," Richards (1939, 291), others deny the value or possibility of such reconstruction, and stress the need to study culture contact as a continuous process of interaction between groups with different cultures, Fortes (1936, 89). In all cases however, the study of primitive societies has shifted its emphasis from uncontaminated " savages " to " subjects " of various colonial powers.

III

I have sketched briefly and with admitted oversimplification the historical background influencing the study of culture contact; in the remaining section of my address, I propose to outline a method of analysis which will incorporate the tested contributions of different schools. I will try to show that the methods of the historical and functionalist schools must be regarded as complementary, each throwing light on certain aspects of a particular social phenomenon. As different chemicals produce different effects on the same base, so the historical and the functional approach show different facets of the situation of culture contact. Only with this full information can we hope to make comparisons from which we can draw valid generalisations on the evolution of society.

The functionalist is trained as a field worker, whose task is to study Native life as it is actually lived, and to do this he employs a wide range of tested techniques. These techniques are being extended, making for greater accuracy and objectivity. The worker lives for a year or two in the midst of the tribal

culture, learns the language of the people observes the every day routine, attends festivals and court cases, collects genealogies, texts, life histories, works out questionnaires and, to an increasing extent, gathers statistics. He selects his informants from different status groups, aware that young and old, conservative and progressive, men and women, aristocrat and commoner, represent different interests. His task is obviously more difficult in a society that is undergoing rapid change, than in one which is developing slowly and in one which is highly specialised and heterogeneous than in one which is simple and homogeneous. But the so-called functionalist technique of the field worker can be extended from the simple to the more complex sphere, and where various aspects of European culture have become established in Native life, he can include in his purview the administrator, the missionary and other contact agents. Moreover it is gradually being recognised that the field worker who is also a theorist should not limit his studies to a single area but should attempt to do research among more than one tribe. This would lessen the tendency to generalise from a single area and to develop a parochial outlook. Team work in which the anthropologist cooperates with other specialists in the social sciences is also being developed, as for example in the Nyasaland nutritional survey. As primitive societies become more highly differentiated, the anthropologist, who is not a Jack-of-all-trades, correlates his data with the findings of other experts.

Various special devices to study the process and effects ot change have been evolved. Thus Redfield, Hunter, the Culwicks, Richards and others have worked in areas selected according to the types and intensity of contact, and Schapera has investigated development in the same community over a period of some ten years.

Apart from his work in the field, the anthropologist handles historical documents. From the age of European penetration we have written records varying in reliability and detail, but these must be carefully scrutinised and their author's credentials ascertained before they are used as factual evidence. Though they are usually too anecdotal or inadequate to provide any full picture of a period they are useful in elucidating trends and policies. Thus the land situation in modern Swaziland required research into the early concessions, and a dispute between the present paramount chief and the administration could only be understood after studying various conventions on which the Swazi based their case and which the administration was prepared to ignore.

By stressing the need for a historical perspective I do not consider that it is possible or necessary to trace the origin of customs and institutions rooted in a primeval past which cannot be explored, but I wish to emphasise that no society has any existence divorced from its past.

From a study of the functioning society it soon becomes clear that the sum total of culture consists of the interlocking of ever changing parts. Because the field worker's task is to study Native life in action, this does not mean that all activities have the same importance for the Natives or belong to the same period. As the plough comes in, the hoe goes out; as trade unionism develops, tribal loyalties wane. To describe culture as if it were of a single time level is to disregard its dynamic nature, and to treat society as a catalogue of isolated traits is to ignore the fact that it consists of individuals and groups forever acting on each other.

Detailed reconstruction of the growth of tribal culture is impossible because of the Natives' approach to time (a reflection of his general weltanschauung), and because of the absence of written records. Preliterates remember isolated episodes, droughts, battles, famines, names of kings and heroes, but these are divorced from their full social content. There is no clear chronological sequence of events and the different periods of the past become merged in legend. At the same time those legends that linger on into the present often provide evidence of inter-tribal contact, and attitudes shaped by historical experience may continue even if the experience is forgotten. Distorted ideas of the past sometimes glorified, sometimes belittled, are fundamental to all national and group action, and, as part of living history, shape existing institutions.

In Africa the initial impact with agents of European culture occured at least a hundred years ago, and in some places very much further back, and no record may remain of the behaviour of the first trader, missionary or government official, and the response which he met from the people. But subsequent rationalisation of the initial impact may well affect social interrelationships. In Swaziland the path for domination by the Europeans was partly prepared even before their arrival. Informants told me how their ancient king Mswati dreamed that the ancestors had advised him not to fight the newcomers of a strange species. Furthermore, within every tribal structure there can be found customs and beliefs which give an indication of periods of past development. Thus reflected in the political structure of the Swazi tribe is the amalgamation of three groups of clans; the earlier inhabitants of the country, the conquering invader and the later comers. Peculiarities of traditional social configuration may well be traced to historical contacts. When accurate historical knowledge is absent and is replaced by speculation, the speculation must be rejected not the value of historical knowledge.

Here we can refer to the historical approach of the American diffusionists. The way in which traits are distributed across tribal boundaries may indicate that some traits are earlier than others, and may throw useful light on influences from outside that have affected pre-existing structures. We need only

cite the analysis of the introduction of the horse (Wissler, 1914), or the peyote cult in America (Radin, 1914). Thus an insight into the historical development of a particular community can be extended by studies of neighbouring communities.

When applied to modern conditions, the diffusionist approach must however, be modified. Geographical proximity has become less important than political control which may be exercised from thousands of miles away. Artificial boundaries are thereby introduced into a single homogeneous area; thus there are now major distinctions between the Swazi living in Portuguese territory, the Protectorate and the Union of South Africa. The diffusionist method must be used as a further extension in time of what I call the full functional historical approach. This will take into account the type of government, religion, economic goods and other conditions that are introduced both from neighbouring areas and from distant centres.

This brings us to the question of comparison. When an anthropologist has produced an historical function study of a particular community, his findings must be compared with others in order to obtain general principles underlying cultural development. Here the work of Radcliffe Brown is of outstanding importance. In his address before the British Association he indicated the need for, and the methods of, a comparative Sociology which would obtain general principles of social structure and development. As he points out " Comparison in this science has very largely to take the place of experiment in other sciences " (1931: 160).

The value of comparisons will depend on our ability to abstract units which are really comparable and which do not bear mere superficial resemblances. Our difficulty lies in the very nature of our material, for cultural traits constantly change their meaning and social groups their function and their form. In the past, anthropological comparison was often vitiated by isolating customs and objects from their context, by using terms such as totemism, clan, blood brotherhood, without clear definitions, and by extending the same label to cover multiple phenomena.

A realisation that traits derive their meaning within a social, as well as a geographical framework has led to the concept of cultural types. A culture type is a generalisation of basic structural similarities found in a number of societies. In the first place the type is abstracted within a limited geographical region and then compared with other societies and types from more distant regions. This first stage of analysis has been accomplished by Radcliffe Brown for the kinship system of the Australians; and a more generalised application was attempted by Fortes and Evans-Pritchard for the political system of eight African tribes, (Fortes and Evans-Pritchard, 1940, 1-23). These studies deal largely with structural correlations; correlations for

example, between political authority and kinship grouping—which, when expressed as general principles must also cover historical influences and variations introduced by individual leaders.

Since the culture type usually includes a number of tribes living close together, it may coincide geographically with a culture area, but each is approached from a different angle. While students of the culture type try to obtain general principles of structure from comparing historical functional data, students of the culture area, working with isolated historical traits, seek to trace their diffusion. Herskovits (1930), e.g., using the diffusionist approach, mapped Africa into eight culture areas and dealt particularly with the East African cattle area which includes tribes structurally as diverse as the Swazi of the Protectorate and the Nuer of the Anglo Egyptian Sudan. The Swazi have a dual monarchy, a well developed administrative system, a number of graded courts, and within this society there is differentiation of wealth and privilege between the hereditary aristocrats and the commoners. The Nuer on the other hand belong to the type of primitive society which lacks centralised authority, administrative machinery and judicial institutions, and in which there are no sharp divisions of rank, status, or wealth, Fortes and Evans-Pritchard (1940, p. 5). Yet both societies, from the diffusionist approach, share a complex of traits centring in cattle, and which can be traced through a number of geographically intermediate tribes of various types.

In my opinion, while the culture area and culture type approach are distinct, they are complementary. I have already indicated how an analysis of diffusion increases historical perspective of a particular society. The comparison of a number of societies studied by the historical and functional techniques indicates how and why societies change. Such comparisons must take into account the aims, agents and methods of interacting groups and also the geographical range of their influence. This would enable us to show correlations between certain types of society and certain types of pressure or stimulus. Needless to state, these correlations are not necessarily causal relations. The most careful initial work on lines somewhat similar to those mentioned above is provided by Schapera in his recent book, wherein he analyses the part played by tribal governments as agents of change in eight contiguous Tswana tribes, all of whom belong to one cultural type (Schapera, 1944). But full comparative studies of societies affected by contact with other cultures are still almost non-existent, and the theoretical basis for such comparison is not usually clarified.

In conclusion let me reiterate that culture contact is an essential part of the scope of modern anthropological research. It has recognised practical implications and opens new fascinating theoretical possibilities. If we limit anthropology to a study

of function and structure we overemphasise the tendency to integration and consistency within individual primitive societies. On the other hand, to atomise culture and chase selected traits over the globe ignores the essential feature of society—the human milieu. The two approaches, which we can label the functional historical and the comparative are both essential and complementary. The process of contact must be studied as an historical as well as a sociological phenomenon evident in lifferent areas and social groups and expressing itself in the adaptive behaviour of human beings.

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NOTE ON SOME GEOMETRICAL PROPERTIES OF THE COEFFICIENT OF CORRELATION

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1. Given a set of N points, each of which is associated with a pair of correlated variables x, z, the mean values of the variables being taken, for simplicity, as zero

The Second Moment of the system of points about the axes of x and z we define as

$$\left.\begin{aligned} \Sigma\, z^2 &= N\sigma_z^2 \\ \Sigma\, x^2 &= N\sigma_x^2 = A \end{aligned}\right\} \quad \ldots\ldots \quad (1.1)$$

Transform to a new variable y given by

$$y/\sigma_x = z/\sigma_z \quad \ldots\ldots \quad (1.2)$$

Then

$$\Sigma\, y^2 = N\sigma_x^2 = A$$

so that the variables x and y now have equal variance.

The Product Moment of the set of points (x, y) is defined as

$$D = \Sigma\, x\, y = \frac{\sigma_x}{\sigma_z}\, \Sigma\, x\, z \quad \ldots\ldots \quad (1.3)$$

The Coefficient of Correlation r_{xy} between x and y is

$$r_{xy} = \frac{\Sigma xy}{\sqrt{(\Sigma\, x^2)\ (\Sigma\, y^2)}} = \frac{D}{A} \quad \ldots\ldots \quad (1.4)$$

$$= r_{xz}$$

We intend giving some new geometrical properties of this quantity r_{xy}.

2. Take any pair of perpendicular axes OL, OM through the origin, making angle θ with the x and y axes respectively. Let the co-ordinates (x, y) referred to OL, OM be (ξ, η) where

$$\xi = x \cos\theta + y \sin\theta$$
$$\eta = y \cos\theta - x \sin\theta$$

The second moments of the system about the new axes are

$$\left.\begin{aligned} \Sigma\eta^2 &= A - D \sin 2\theta \\ \Sigma\xi^2 &= A + D \sin 2\theta \end{aligned}\right\} \quad \ldots\ldots \quad (2.1)$$

while the product moment is

$$\Sigma\xi\eta = D \cos 2\theta \quad \ldots\ldots \quad (2.2)$$

It is clear that if $\theta = 45^\circ$ or 135°,

$$\left.\begin{aligned} \Sigma\eta^2 &= A - D = \alpha \\ \Sigma\xi^2 &= A + D = \beta \end{aligned}\right\} \quad \ldots\ldots \quad (2.3)$$

and that these are the maximum and minimum values of the Second Moment about all possible axes through O. The axis corresponding to the minimum Second Moment is that defined in an earlier paper (Bleksley, 1942) as the "*line of best fit,*" for the set of points.

3. Along the axis OL lay off a line of length p such that p^2 is inversely proportional to the second moment $\Sigma\eta^2 = \alpha$ about that axis. Then taking the factor of proportionality for convenience as unity, the locus of the end point of this line is given by

$$A\,x^2 + A\,y^2 - 2\,D\,xy = 1 \quad . \quad . \quad . \quad . \quad (3.1)$$

which is the equation to an ellipse, which in accordance with a terminology familiar in the theory of moments of inertia we may call the *Momental Ellipse* for the given set of points.

The principal axes of the momental ellipse may be shown by the usual methods to be the lines

$$y = \pm x \quad . \quad . \quad . \quad . \quad . \quad (3.2)$$

and the equation of the ellipse referred to its principal axes is

$$\alpha\,x^2 + \beta\,y^2 = 1$$

where α, β are given by (2.3).

The semi-axes a, b and the eccentricity e of the momental ellipse are given by

$$\left.\begin{aligned} a^2 &= 1/\alpha = 1/(A - D) \\ b^2 &= 1/\beta = 1/(A + D) \\ e^2 &= (\beta - \alpha)/\beta = 2D/(A + D) \end{aligned}\right\} \quad . \quad . \quad (3.3)$$

Hence we have, from (1·4) and (2·3)

$$\left.\begin{aligned} r_{xy} = D/A &= (\beta - \alpha)/(\alpha + \beta) \\ &= (a^2 - b^2)/(a^2 + b^2) \\ &= e^2/(2 - e^2) \end{aligned}\right\} \quad . \quad . \quad (3.4)$$

These equations relate the coefficient of correlation to the semi-axes and eccentricity of the Momental Ellipse.

4. Imagine a uniform lamina bounded by the Momental Ellipse. The moments of inertia of such a lamina about its principal axes are $M\,b^2/4$, $M\,a^2/4$ respectively. If we name these moments of inertia I_1, I_2 respectively, then the moment of inertia of the lamina about a third axis perpendicular to the principal axes is $I_3 = I_1 + I_2$. We then have

$$\left.\begin{aligned} r_{xy} &= (I_2 - I_1)/(I_2 + I_1) \\ &= (I_2 - I_1)/I_3 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (4.1)$$

The coefficient of correlation can therefore be regarded as a measure of the relative moments of inertia of the momental elliptic lamina about its principal axes.

5. An alternative geometrical representation of r_{xy} is provided by the following construction: Let PG be the normal to the momental ellipse at P, G being the point where the

normal cuts the major axis. Let GP be produced outwards to Q so that $PQ = GP$. Then it can be shown (Smith, 1901) that the locus of Q is an eclipse whose eccentricity is

$$(a^2 - b^2)/(a^2 + b^2) = r_{xy}.$$

6. The degree of covariance between the two variables x, y can therefore be represented, not only by the coefficient of correlation but also by the characteristics of the momental ellipse, such as the eccentricity e or the ellipticity $h=(a-b)/a$. In terms of the observed constants A, D of the system of points we have

$$\left.\begin{aligned} r_{xy} &= D/A \\ e^2 &= 2\,D/(A + D) \\ (1 - h)^2 &= (A - D)/(A + D) \end{aligned}\right\} \quad . \quad . \quad (6.1)$$

These relations provide a simple geometrical representation of the correlation coefficient. Thus, if for convenience we take $A = 1$, i.e. choose the scale so that the variance of our variables is unity, we have the following table showing the principal data concerning the momental ellipse for a series of values of the coefficient of correlation.

TABLE.

r_{xy}	For the Momental Ellipse.			
	a	b	e	h
0·00	1·00	1·00	0·00	0·00
0·2	1·12	0·91	0·59	0·19
0·5	1·41	0·82	0·82	0·42
0·8	2·24	0·75	0·94	0·67
0·9	3·16	0·725	0·97	0·77
0·95	4·47	0·716	0·99	0·84
0·99	10·0	0·709	0·997	0·93

For small values of r_{xy} (i.e. for D small), we have approximately

$$r_{xy} = h = e^2/2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6.2)$$

while for large values of r_{xy}: $r_{yx} = e^4$ . . . . (6.3)

7. The Second Moments of the system of points about the principal axes are

$$\Sigma\eta^2 = A - D = N\,\sigma^2$$
$$\Sigma\xi^2 = A + D = N\,\rho^2$$

A measure of the "goodness of fit" of the major axis to the given points was suggested in the paper previously quoted ([3]), viz.:

$$\frac{\sigma}{\rho} = \sqrt{\frac{A - D}{A + D}} = 1 - h$$

Alternative measures of this goodness of fit would clearly also be provided by

$$e^2 = (\rho^2 - \sigma^2)/\rho^2$$
$$\text{or } r_{xy} = (\rho^2 - \sigma^2)/(\rho^2 + \sigma^2)$$

which shows that the coefficient of correlation can be regarded as a measure of the " goodness of fit " of the given system of points to the " line of best fit."

8. The regression lines are given by

$$y = r_{xy} \cdot x$$
$$x = r_{xy} \cdot y$$

which, on transforming to the principal axes, become

$$y = \pm \frac{b^2}{a^2} x = \pm (1 - e^2) \cdot x \quad . \quad . \quad . \quad (8.1)$$

The regression lines are thus equally inclined to the major axis which is also the " line of best fit."

By a familiar result ([4]), the equation of the diameter conjugate to

$$y = m\, x \text{ is } y = - b^2\, x/a^2\, m$$

Hence by (8·1) the regression lines are diameters conjugate to the diameters

$$y = \pm\, x$$

which are the equations of the original axes referred to the principal axes of the Momental Ellipse.

Alternatively, if L is the semi-latus rectum,

$$L = b^2/a$$

Hence, referred to the principal axes as axes of co-ordinates, the regression lines are given by

$$y = \pm\, L \cdot x/a$$

which provides an alternative representation of these lines.

Summary.

For a given system of points in a plane, a " Momental Ellipse " is defined and its geometrical properties discussed. It is shown that the coefficient of correlation between two variables of equal variance is closely related to the eccentricity and ellipticity of the momental ellipse, so that the shape of this ellipse is a valuable geometrical representation of the degree of covariance between the two variables.

The diameters of the momental ellipse which are conjugate to the diameters along the original axes of co-ordinates are shown to be identical with the regression lines.

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A CONDUCTIVITY METHOD FOR THE ESTIMATION OF SOIL WATER MOVEMENT, III—SEASONAL CHANGES IN SOIL MOISTURE CONDITIONS

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With 4 Text Figures.

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I—The Soil Site and General Purpose of the Investigation.

In Paper 1 of this series (Coutts, 1937), the electrical conductivity method for the estimation of soil water movements was discussed, mainly from the point of view of laboratory experiments, and in Paper II (Coutts, 1938) the method was applied to a study of the movement of soil water at a site in the Natal University College grounds during the season 1937 to 1938. One month after the completion of the observations discussed in Paper II, a new experiment was started by burying twelve electrodes in a heavier soil than that used in the earlier work. The objects in view in this new experiment included the collection of data over a longer period of time and to a greater depth in the soil, so that fuller information could be obtained on the seasonal variations in the moisture status of the soil.

The site selected lies on a strip of level, grass-covered ground from which the run-off was small. From the date at which the electrodes were buried (18th July, 1938), it has been undisturbed except for cutting the grass once or twice a year. The soil lies on a doleritic band which runs across the Natal University College grounds, and contains much detritus from the decayed doleritic sill. To minimise the disturbance of the soil above the electrodes, a hole was dug with a vertical side, and the electrodes were pressed into the undisturbed soil of this wall; the hole was then refilled with the material that had been taken from it. The profile exposed in this hole showed four distinguishable strata, which may be described as follows:

0 to 5 inches: Chocolate brown soil, granular structure, many roots; 47·1 per cent. clay.

5 to 9 inches: Chocolate brown soil, granular structure with some gravel, moderate number of roots; 51·0 per cent. clay.

9 to 17 inches: Brownish yellow soil, cloddy structure with some gravel, few roots; 55·2 per cent. clay.

17 inches + : Yellowish red clods, with decomposed shale, very few roots; 61·9 per cent. clay.

The clay percentages quoted above were obtained by the International Soda method (Robinson, 1934).

The depths below the surface at which the electrodes were buried are shown in Table I.

TABLE I.

Depth (inches) of electrodes below surface.

A		B		C		D		E		F
2·0	...	3·5	...	4·3	...	8·1	...	8·7	...	9·4
G		H		I		J		K		L
13·2	...	15·0	...	16·1	...	23·8	...	25·1	...	26·9

There had been a precipitation of 0·62 inches of rain on 7th July, 1938, and on 18th July, 1938, the moisture contents in the four strata were as follows: 0 to 5 inches, 22·4 per cent.; 5 to 9 inches, 20·4 per cent.; 9 to 17 inches, 17·8 per cent; 17 inches +, 25·0 per cent.

A few preliminary measurements of the conductivities between the various electrode pairs were made about a week after the hole had been refilled; regular observations commenced on 26th September, 1938, and continued until 8th October, 1943. From 26th December, 1938, onwards, a Casella recording rain-gauge was available for determining the intensities of the precipitations. The conductivities were measured with the apparatus described in Paper I; in the five years for which the experiment continued, about 10,000 readings were taken. A chart showing the relationship between the time and the conductivity for each electrode pair was constructed for the whole series (c.f. Fig. 1 of Paper II), and this was useful in the general examination of the results. Sections of this general graph appear in Figs. 1, 2 and 3 below, but no useful purpose would be served by reproducing the complete graph on a small scale.

Broadly speaking, it may be said that the soil moisture content tends to decrease at the end of summer, or in autumn, and through the winter, until the onset of the next summer rains, and this rough generalisation can be used to divide the data for discussion. It is convenient to take the months from September to February (inclusive) as "summer," March and April as "autumn," and May to August (inclusive) as "winter." No "spring" season is distinguishable; the change from winter to summer is usually fairly abrupt, with September as a transitional month whose characteristics fluctuate from year to year according to the date at which appreciable rains commence. In Section 2 below, we shall describe the main points of interest in the experimental results (a) during autumn, winter, and early summer, until a heavy precipitation has wetted the whole profile; (b) in

subsequent drying period at the end of the summer rains. Section 3 contains a general discussion of the results.

2—Experimental Data.

(a) *Autumn, Winter, and early Summer, Seasons 1938 to 1942.*—The data summarised in this section refer to periods in which the soil is wetted, either by isolated winter precipitations or by the earlier rains of summer. The drought year of 1941 is dealt with in rather more detail than the others, because the exceptionally late start of the rainy period makes the effects under consideration particularly clear, and the results are shown graphically in Figs. 1 and 2.

(i.) *1938*: The rainfall for September (to the morning of 30th September, 1938), was 0·27 inches. On the evening of 30th September, 1938, there was a storm, yielding 0·80 inches in three-quarters of an hour, and the rain penetrated to a depth of 3·5 inches. The cumulative effects of rains totalling 3·82 inches in 22 days (to 27th October, 1938) gave an appreciable effect to a depth of rather more than 8·1 inches. During a heavy storm, with hail and rain on the afternoon of 27th October, 1938, there was a precipitation of 3·67 inches in four hours, and in consequence the whole profile was wetted, at least to the depth of the lowest recording electrode (26·9 inches), and probably considerably lower.

(ii.) *1939*: From 14th March, 1939, to 18th July, 1939, the only significant precipitation was a steady fall of rain totalling 1·56 inches in 18 hours on 20th May, 1939, and this gave a large increase in conductivity to a depth of 16·1 inches. From this date until 18th July, 1939, there occurred a few light showers (totalling 0·16 inches); on the afternoon of 18th July, 1939. there was a fall of 0·48 inches, of which 0·40 inches fell in two hours, and this caused a small increase in conductivity in the electrode pair AB, indicating that the effective penetration was between 2 inches and 3·5 inches—say 2·8 inches. Similar effects were observed after rainfalls of 0·62 inches in three hours (16th August, 1939), of 0·48 inches in 26 hours (5th to 6th September, 1939) and of 0·40 inches in two hours (12th September, 1939). It will be noted that there were considerable dry intervals between these precipitations; when there was a further rainfall of 0·45 inches (of which 0·3 inches fell in two hours) on 15th September, 1939 (i.e., within three days of the preceding rain), it was effective to a depth of 8·1 inches. A rainfall totalling 0·92 inches, occurring in a series of heavy showers between 21 hr, 24th September, 1939, and 08 hr, 25th September, 1939, produced wetting to a depth of 16·1 inches.

(iii.) *1940*: After a dry period from 6th May, 1940, rain totalling 2·52 inches fell practically continuously for 32 hours (18th to 19th June, 1940), and the whole profile was wetted (see

Fig. 3a below). There was no further rain in June or in July, and only light showers, aggregating 0·37 inches, fell in August and early September. There was a rainy period from the night of 13th September, 1940 to that of 14th September, 1940, with a total precipitation of 0·63 inches of which about one-third fell between 21 hr and 22 hr, 13th September, 1940, one-third in a shower of a quarter of an hour duration at 18 hr, 14th September, 1940, and the remainder as a light drizzle. These rains caused only a slight increase in conductivity in the first electrode pair, and no further response was obtained from showers aggregating 0·43 inches between 14th September, 1940 and 30th September, 1940. Within the 24 hours from the morning of 30th September, 1940, there was a precipitation of 0·76 inches, of which 0·30 inches fell in one hour (30th September, 1940) and 0·23 inches fell between 08 hr and 10 hr, 1st October, 1940; the effective penetration was to a depth of 8·1 inches. Further responses to the same depth during the remainder of October call for no particular comment. The first response of the season in the lowest electrode pair occurred on 9th November, 1940, continuous rain to an aggregate of 1·83 inches falling between 12 hr, 8th November, 1940, and 08 hr, 9th November, 1940.

(iv.) *1941*: On 2nd January, 1941, a heavy rainfall of 1·20 inches in three hours penetrated at least to the lowest electrode pair, but although there was a moderate rainfall for the remainder of the summer, none of the individual precipitations was sufficient to penetrate to this depth. In March, a precipitation of 0·8 inches in 7 hours, followed by 0·91 inches in half an hour, penetrated to 23·8 inches, and a fall of 1·04 inches extending over three days (22nd to 25th March, 1941) penetrated to 9·4 inches. As will be seen from Fig. 1, 0·89 inches of rain in two days (4th to 5th April, 1941) also penetrated to 9·4 inches, and 0·70 inches of rain in 19 hours (20th April, 1941) was slightly more effective —after this rain, a slight "hump" appeared in the conductivity curve for the electrode pair FG. During the succeeding dry winter months, there was general desiccation, and by the end of August the conductivities in all the strata had fallen to low levels. Of the September rainfall of 1·36 inches, details are given in Table II for all the precipitations which exceeded 0·1

TABLE II.

Details of rainfall (inches) 16th to 22nd September, 1941.

Date.	Hrs.	Rain.	Date.	Hrs.	Rain.	Date	Hrs.	Rain.
16	15		19	18		21	08	
		·03			·21			nil
	22		20	06			14	
		·17			nil			·11
	23½			15		22	03	
					·27			
			21	08				

inches within 24 hours. It will be seen that there was one fall of moderate intensity but short duration on the night of 16th September, 1941, and that rain fell most of the time between the afternoon of 19th September, 1941 and the night of 21st September, 1941 (except on the morning of 20th September, 1941) with a total precipitation of 0·59 inches. Yet it is clear from Fig. 1 that these rains had a negligible effect in increasing the moisture mobility even in the uppermost electrode pair. Between 27th October, 1941 and 2nd November, 1941, the following precipitations occurred: 0·3 inches in two hours, 0·32 inches in five hours, 0·19 inches in 12 hours, and 0·22 inches in 12 hours. As there was a small response in the electrode pair CD, the resultant penetration must have extended to a depth of about 6 inches. On 16th November, 1941, a rainfall of 0·66 inches in five hours penetrated to approximately 9 inches. In December, after eight light precipitations aggregating 1·99 inches, there was a small increase in mobility to a depth of 8·1 inches. The first complete wetting of the profile occurred after two storms on 7th January, 1942, when there was a fall of 0·67 inches of rain in one hour, followed by 2·00 inches to two hours.

(v.) *1942*: Two storms within ten hours of each other yielding 1·30 inches of rain on 19th March, 1942, caused penetration to the lowest electrode pair. After a dry period, a light rain which continued for 36 hours (18th to 19th April, 1942), giving a total amount of 0·64 inches, had a negligible effect even in the uppermost electrode pair; but a precipitation of equal amount, falling in ten hours (17th May, 1942) gave a slight response to a depth of approximately 6 inches. After sundry ineffective light rains in the winter months, penetrations to a depth of 8·1 inches resulted from a fall of 0·70 inches in 48 hours (26th to 27th August, 1942) and also from a fall of 0·26 inches in one hour, four days later (31st August, 1942). Three further penetrations to the same depth occurred between the end of August and 29th October, 1942, when a storm yielding 1·78 inches of rain in four hours gave a rapid response to a depth of 16·1 inches, and the conductivities of the strata at greater depths than this were still rising slowly during a period of moderate rains which penetrated directly to a depth of 8·7 inches, and until complete wetting of the profile followed a precipitation of 1·50 inches on 11th November, 1942.

(b) *Winter, 1943*.—The abnormal nature of the winter of 1943 is shown by the data in Table III, which gives the rainfall normals for the winter months for 48 years ending 1942 and the rainfalls for the same months in 1943. These data from the Maritzburg Mental Hospital are not strictly comparable with those for the Natal University College grounds, but they are quoted in order to compare the 1943 readings with the average values over a much longer period than is available from our own records at Natal University College.

TABLE III.

Rainfall normals (inches) for 48 years to 1942, April to August, compared with rainfall for same months in 1943. Data from Maritzburg Mental Hospital.*

	April.	May.	June.	July.	August.
48 years to 1942 ...	1·90	1·20	0·51	0·53	0·94
1943	10·07	3·52	0·89	3·78	4·64

During this season, the driest period was from 6th July, 1943 to 21st August, 1943, the rainfall between these dates totalling 0·33 inches. The whole soil profile was wetted after three days' continuous rain, totalling 3·15 inches; and ending on 6th July, 1943, and there was again a large effect in the lowest stratum on 22nd August, 1943, after rain had fallen continuously for 30 hours, to a total of 1·20 inches. It is interesting to compare the results for this season with those for the drought season of 1941, and this is done in Fig 1, where the conductivities in the various strata for the two years are plotted on the same graphs. Although (for reasons discussed in Papers I and II) the maxima on the curves cannot be taken as quantitative measures of the amount of water received by the soil, the same objections do not apply to the use of the low conductivities recorded during relatively dry periods as estimates of the moisture mobility in the soils at these times. The conductivities recorded in the winter of 1941 were the lowest obtained in the course of the whole experiment, and the effect of the frequent rains in the winter of 1943 in maintaining a relatively high degree of moisture mobility throughout the profile is clearly shown in Fig. 1. Later in this paper, it will be shown that an estimate can be made of the conductivity level at which the moisture in the soil is unavailable to plant roots. The conductivity under these conditions has been called the *lentoconductivity*, and its values for the various strata in the profile are indicated by the horizontal arrows in Fig. 1 and in Fig. 2. It will be noted that the conductivities during the winter of 1943 remained for the most part well above the lentoconductivity levels. The beneficial effect upon the vegetation of this unusually favourable winter moisture status was shown by the exceptionally luxuriant growth which occurred in early summer despite a September rainfall (0·65 inches) well below the average. A further point of interest worthy of mention in connection with the results for this season is the greatly increased effect of moderate precipitations upon the soil when it is already moist. For example, one may compare the effect of the precipitation of 0·57 inches on 13th May, 1943, which increased the conductivity to a depth of 23·8 inches, with the small effects of 0·64 inches of rain in April and in May, as recorded in Section 2a (v) above.

* Department of Irrigation (1939): Rainfall normals up to the end of 1935; subsequent data by courtesy of Superintendent, Maritzburg Mental Hospital.

(c) *Summer and the subsequent Autumn and Winter drying Periods, Seasons 1938/39 to 1942/43.*—In a summer in which the rainfall approaches average values, the precipitations are fairly frequent, and often of a torrential character, so that there are few occasions when the moisture status in the subsoil falls to a low value; in the period covered by the observations, only three cases occurred in which the two lowest strata reached their lentoconductivity levels (December, 1939; February, 1941; and February, 1943). But the climatic conditions are such that drying is rapid near the surface, and summer drying of the upper strata is a normal occurrence. Towards autumn, as the rainy season ends, there is a progressive drying throughout the profile, and in the event of a heavy isolated precipitation in winter, there is an abrupt rise in the conductivities of the strata to which the moisture penetrates, followed by a gradual decline; cases of this kind have already been mentioned in Section 2a. The general nature of the curves obtained is illustrated in Fig. 3, which shows the results for the uppermost electrode pair AB and for one of the lower electrode pairs, HI, (a) for June, 1940, and (b) for part of the summer of 1942. The features of the winter curves are self-evident; as regards the summer curves. one may say that, broadly, the curve for the upper stratum shows numerous "hills" and "valleys" representing the fluctuating effects of rainy and of comparatively dry periods, while in the lower stratum the fluctuations are less violent, and the curve shows a general upward trend—this trend being most pronounced, of course, in the wettest seasons. The detailed analysis of the fluctuations in the upper strata would be a length process, and one which would not be likely to lead to any results of general importance, since the incidence of the hills and valleys varies according to the rainfall characteristics of the particular season. The question of the periods for which available moisture remains in the various strata in the intervals between the summer rains and in the ensuing autumn and winter is, however, of practical interest, and the data have been examined from this point of view. Table IV shows the number of days, measured from that upon which a particular stratum was wetted by direct penetration, for which the conductivity remained above the lentoconductivity level. All the observations obtained in the course of the experiment are included in this Table, except for a small number recorded in the summer of 1938/39, during the first cycle of wetting and drying after the soil had been disturbed by the insertion of the electrodes. For convenience, Table IV also includes cases of drying after early summer rains in September. Where the drying period exceeded one month, the results are entered under the month covering the mean of the first and last dates of the period concerned. It is emphasised that the times for each stratum are measured from the date of wetting by *direct* penetration, no account being taken in this connection of smaller subsequent precipitations affecting strata above it; the

indirect effect upon the drying period of such penetration is mentioned in the next Section, but the method adopted for specifying the periods has the advantage that it shows immediately the time for which mobile water is retained under the prevailing conditions.

During the dry periods of the year, the conductivities in the upper strata always fall to low values, but the lower strata remain moist for a considerable time, and in Table V there appear the dates between which the strata at depths greater than 8 inches were in a condition in which their conductivities were below their lentoconductivity levels. These data are discussed in Section 3b below.

3—Discussion.

(a) *Wetting the Soil after a Dry Period.*—In Section 2a, some examples were given of the small effect of the early summer rains in producing any appreciable effect upon the moisture mobility even in the upper strata of the soil. For instance, in the period September to December inclusive, 1941, 7·78 inches of rain fell, but there was only one occasion upon which the penetration extended as far as 9 inches. These rains included the rainy period in September for which details were given in Table II; such a period is often popularly described as one of "good soaking rains," but our results show that their effectiveness in increasing the mobile moisture in the soil was in fact negligible, and that they could have had but little influence upon the amount of water available to plants (except for surface rooted plants). There may have been some improvement in the moisture status in the uppermost 2 inches of the soil, above the first recording electrode, but even this is doubtful; for after a lengthy period of low rainfall, a considerable amount of the immobile (or imbibitional) water has been removed from the soil, and most of the water supplied by the first rains is absorbed by the soil colloids, and is not readily available. Only after the imbibitional water has been replenished does an additional rainfall provide available moisture. Thus, in the early summer of 1940, while the precipitation of 0·63 inches (13th to 14th September, 1940) had only a very small effect at a depth greater than 2 inches, the slightly greater precipitation of 0·76 inches (30th September, 1940), which fell at approximately the same intensity, gave effective penetration to a depth of 8·1 inches; the difference between these two results being in the main accountable to the supply of imbibitional water by the above-mentioned rainfall of 13th to 14th September, 1940, and by light rains in the intervening period. Similar cases are to be found in each of the seasons described in Section 2a, and the results are of practical interest, in that they indicate the need for considerable caution in assessing the effect upon the soil of these early rains. If, for instance, ploughing had been undertaken after rains such as those received in September, 1940, it would have been found that the land was too dry for efficient cultiva-

tion; in that particular season, adequate wetting to a depth of 8·7 inches took place on 16th October, 1940, but thorough wetting of the whole profile was delayed until 8th November, 1940, when 1·83 inches of rain fell in 20 hours.

From an examination of the data collected in the five years for which the experiment continued, a table was drawn up, showing the amounts of rain (falling continuously) which were necessary to penetrate to the depths specified by the various electrode pairs; in cases in which there was a large response in one electrode pair and a small one in the next lower pair, the effective depth of penetration has been taken as half-way through the lower of the two strata. As might be expected, the results varied widely, since they depend both upon the precedent moisture status in the soil, and also upon the intensity of the rainfall. We are not, however, primarily concerned with the intensity factor, since all rains which fall continuously in sufficient quantity to penetrate to appreciable depths have fairly high intensities. The value of two or three days of "heavy drizzle" can be discounted, for a considerable proportion of the water received from such a precipitation is retained by the grass cover, or is evaporated during a bright interval, and never reaches the soil surface. The results are shown in Fig. 4. It will be seen that nearly all the points lie in a band between two smooth curves.* The upper curve gives information as to the least amount of rain which can, under the most favourable conditions, in an already moist soil, give an additional effect at a specified depth; while the lower curve shows the precipitation necessary to penetrate to the various strata, starting from conditions such as those prevailing at the end of a normal winter. It appears that information of this kind could be of value in the field. If, for instance, a particular agricultural operation on a soil such as the one now under experiment depends upon the soil being wetted to a depth of 9 inches, then the graph shows that the operation cannot be carried out until there has been a continuous rain giving approximately 1 inch. In the years from 1938 to 1942, the dates at which such rains occurred were 11th October, 1938, 25th September, 1939, 16th October, 1940, 19th November, 1941, and 29th October, 1942; the application of this criterion therefore provides another warning against an over-optimistic assessment of the value of September rains.

The general forms of the curves in Fig. 4 are of interest; while the upper curve shows a fairly regular increase in slope

(*) The five points lying above the upper curve refer to cases in which it was not possible to distinguish between the effects of one precipitation and that of another, occurring slightly earlier, which penetrated directly to a smaller depth. Three points have been omitted from the graph: they refer to cases in which there was a rainfall exceeding two inches, which must have been effective to depths greater than that of the lowest electrode pair, and thus lie outside the range of the experiment.

with increasing depth, the lower curve shows points of inflexion at depths of approximately 3 inches, 10 inches, 15 inches. The form of the upper curve would be expected from the fact that the penetration becomes increasingly difficult as the moisture descends through the profile to soil strata containing increasing amounts of clay (see Section 1). To account for the shape of the lower curve, other characteristics must also be taken into consideration. The nature of the soil is such that even after a relatively short dry period large cracks occur; these may be half an inch wide, and a thin straight rod can be inserted to a depth of about 3 inches. although the fissures are no doubt considerably deeper than this. When there is a moderate precipitation, therefore, a large area of the soil is exposed to it, and unless the precipitation is very intense, most of the water will be rapidly absorbed by the clay colloids and the plant roots, without providing any "free" moisture. Thus, relatively large amounts of rain are required before there can be a significant increase in the conductivity, and the curve relating precipitation to depth of effective penetration is steep, as it is seen to be as far as P in Fig. 4. At rather greater depths, where there has been less severe desiccation, the curve flattens out (in the region PQ); but this change is off-set by the increasing clay content, and the curve becomes steeper again. Finally, the lower strata retain most of their imbibitional water, even in the dry season, and beyond R the curve flattens out again, since once the water reaches these strata, the greater part of it is at once available.

The observations discussed in this paper show that changes in the moisture status of the soil are relatively slow at a depth of about 2 feet, but it would be interesting if data for much greater depths were available also; Nicholson (1935), working with a deep Oxfordshire clay, obtained seasonal variations in the moisture content of the soil when excavations were made to depths as great as 80 feet.

(b) *The Drying Period.*—The question of the period for which available moisture remains in the soil in different strata and at different seasons of the year is an important one, and it is desirable that a quantitative interpretation should be given to such observations of common experience as that the upper strata dry rapidly in summer, while the lower strata remain moist for the greater part of the winter. Data bearing upon these questions have already been given in Tables IV and V, where the times have been quoted for the conductivities to fall to the *lentoconductivity* levels, but the fuller explanation of this term has been deferred until this stage, since it depends upon all the data of which the main characteristics have been summarised in Section 2. From the graph of the complete set of observations, it was evident that there is no sharply defined "endpoint" below which the moisture could be regarded as completely immobile, although in some of the curves, particularly in those for the upper strata and in periods of rapid drying, the change in slope

was sufficiently abrupt to fix the stage beyond which only very slow changes take place, and this state may reasonably be supposed to correspond with the state in which most of the free moisture has been removed. But in most of the curves for the lower strata, where the drying is slow, the change in slope is too gradual to define a point at which there is any abrupt change of direction. There is, however, another criterion which is applicable in such cases; in the curves for dry seasons, after a long period in which the conductivity remains almost constant, there sometimes occur "kinks" in the curve, which represent sudden decreases in conductivity. These discontinuities in the curves are ascribed to cracking of the drying soil, and at this stage it may again be assumed that the moisture has been immobilised. In cases in which the two criteria can be applied at different times on the same conductivity curve, the differences between the values that they give do not differ from one another by more than the differences between replicated results obtained by either of them; and the conductivity levels at which these criteria apply must be near the required limiting value. But a practical difficulty arises when it is required to read from the graphs the times at which the conductivities attain these levels, because the very small slopes of the graphs may cause considerable errors in interpolation. It is therefore more convenient to take a conductivity value 10 per cent. above that found in the manner just explained, and to use this as the lentoconductivity. The mean values of the lentoconductivities so calculated are given, with their probable errors, in Table VI. It is recognised that the numbers of data available for the calculation of the means are too small for the probable error to give a true estimate of their reliability, but it serves to indicate roughly their reliability. The term lentoconductivity has been adopted since it denotes a condition in the soil which represents the upper boundary of a regime bearing an obvious analogy to the lentocapillary point* which is defined as the point below which capillary movement is very slow. Just as the lentocapillary point represents a somewhat higher moisture content that that at the wilting point, so plants exposed to a soil in the condition represented by the lentoconductivity level do not die, but are near the "danger line"; and this is the state of affairs with moderately deeply rooted plants in most winters.

We may now consider further the data given in Table IV for the time required for the soil moisture to fall to the lentoconductivity level after rain penetration. The number of observations available is limited because the intervals between summer rains are often too short to allow the soil to dry; but in some cases it was possible to obtain results by moderate extrapolations. Necessarily, the number of cases occurring in a normal winter is small. Of the many factors which influence the rate

(*) For a discussion of this and other soil water constants see Keen (1922).

of drying of a given soil, the two most important are probably the meteorological conditions at the drying surface and the conditions in the neighbouring soil strata, and of these two the former will have a relatively small effect in the lower strata. For in these lower strata, temperature fluctuations are small, and when drying has proceeded to a stage at which the moisture is confined to the interstitial spaces, the atmosphere in contact with it will be in equilibrium with the saturation vapour pressure over the concave water surface. As regards the influence of the conditions in the neighbouring strata, a good example is provided by the following results for April, 1943. After a dry period from 6th March, 1943, a precipitation of 0·4 inches in 12 hours on 6th April, 1943, had a negligible effect on the conductivities, and 1·04 inches of rain in one hour on 10th April, 1943, gave an appreciable response to a depth of 13·2 inches, the conductivities in lower strata remaining low. The conductivities in the two uppermost strata AB and BC then fell to their lentoconductivity values in 5 days and 4 days respectively. Rains aggregating 1·66 inches between 14th April, 1943, and 16th April, 1943, penetrated to the lowest electrode pair, and the two uppermost strata then reached their lentoconductivities after 7 days. There was continuous rain, aggregating 5·12 inches, from 21st April, 1943, to 24th April, 1943, and this must have saturated the whole profile thoroughly; and when the next heavy rains fell about a week later (30th April, 1943, and 1st May, 1943), the conductivities in the electrode pairs AB and BC were respectively 53 per cent. and 21 per cent. above their lentoconductivity levels. It is therefore apparent that under conditions of high moisture content, capillary transmission can play a considerable part in redistributing moisture through the profile, and this effect explains an apparent anomaly in the curve for the stratum HI in Fig. 3, where (on 14th March, 1942) an increase in conductivity was noted prior to the fall of rain which wetted the upper strata a few hours later. But the high degree of desiccation of the upper strata in a dry season, while the lower strata are still moist, confirms the view that, under these drier conditions, capillary transmission is not effective in maintaining adequate moisture distribution.

If the influence of meteorological factors were very great, then mean values of the times of drying in a given month in each of several years would not have any real significance; but it will be seen from the data in Table IV for the upper strata that the times of drying are reasonably consistent for any particular month of the year, and, further, that there are no significant differences for the periods in the various summer months. It is therefore probable that even when the depth below the surface is as small as 2 inches, the effects of diurnal variations in meteorological conditions at the surface have been smoothed out, although the effects of seasonal variations are still apparent. In Table VII, there appear the means of the results

from Table IV for all cases in which five or more readings are available. These means are derived from all the data relating to each of the strata considered, with the exception of the bracketed figures (which referred to cases of partial wetting), and the results for the summer and winter months are collected in two groups. Reference is made later to some of the individual results for the strata omitted from Table VII.

From the results for the first three strata, for which the data are the most numerous, it will be seen that the times of drying in summer are 6, 6 and 8 days respectively; the approximate equality of the times for the first two strata suggests that the cracking in the drying soil exposes them to similar conditions. The smaller numbers of data for the lower strata are still sufficient to give a fair estimate of the times required for drying in summer to a depth of 20 inches. The results quoted for the winter months indicate that in the three strata, in order of increasing distance from the surface, the ratios of the periods for which the effects of a winter precipitation persist are 3·2, 2·9 and 2·1 respectively times the corresponding summer periods. The decrease in the value of the ratio corresponds with the decrease with increasing depth of the seasonal variation in meteorological conditions, and is also in the direction that would be expected from the fact that in winter the strata immediately below CD are usually drier than in summer, so that there is freer drainage in the former season.

Three cases only appear in Table IV in which one or both of the two lowest strata fall below their lentoconductivity levels in summer. The infrequency of these cases, and the fact that these strata at a depth of more than 20 inches can withstand a relatively dry summer period of at least 7 weeks before reaching their lentoconductivity levels is in accordance with the fact that deep rooted plants seldom suffer in summer from a failure of water supply; they do not appear to require further discussion.

The data appearing in Table V for the winter periods in which the strata at depths greater than 8 inches lay below their lentoconductivity levels are of more interest, since they are concerned with a case of greater practical importance than that of summer drying. The winter drying periods observed in different seasons varied widely in each stratum, and it is not possible to give more than a tentative explanation of the lengths of the observed periods. We shall, however, attempt an approximate analysis of the factors which control the moisture status of the lowest strata in winter. While the aggregate winter rainfall must obviously play a part in the determination of the moisture status of the subsoil, the data show that this is not necessarily the most important factor. For if we compare the seasons 1939 and 1942, the total winter rainfalls (from May to August inclusive) were 3·59 inches and 3·52 inches, yet the dates

at which the two lowest strata reached their lentoconductivity levels were in May in 1939 for both strata JK and KL, while in 1942 the corresponding dates were in August for the stratum JK and in October for the stratum KL (see Table V). The dates in 1942 were therefore nearly as late as in 1940, when the winter rainfall was 8·42 inches. It appears probable that the controlling factor in 1942 was the storage of moisture following the unusually wet latter part of the summer; 21·37 inches of rain fell in the three months January to March. But for the three seasons 1939 to 1941, when the January to March rainfalls were lower (15·57 inches, 12·34 inches, and 9·35 inches respectively), there is a very simple relationship between the date at which the stratum JK reached its lentoconductivity level and that at which the stratum next below it was wetted by direct penetration. Let x denote the day of the year* upon which the latest direct penetration to the stratum KL occurred, and y the day of the year upon which the stratum JK reached its lentoconductivity. Then, as will be seen from Table VIII, the linear equation $y=1{\cdot}24\ x+70$ agrees well with the observations for the three years 1939 to 1941, but fails badly in the year 1942 (and no data are, of course, available for the abnormal winter of 1943). The "failure" of the equation with the 1942 results is simply a restatement of the fact, noted earlier, that in that season moisture was available from the thoroughly wetted profile. But, despite the small number of drier seasons for which it has been possible to test the equation, it suggests that the controlling factor for the subsoil moisture status is the capillary transmission from the stratum next below it. If an equation of this type could be established more generally, for various soil types, it should, when used in conjunction with data similar to those presented in Fig. 4, prove of considerable value in the field.

SUMMARY.

The following conclusions are drawn from an examination of data obtained in the period July, 1938, to June, 1943 for the depths of penetration of rain through a heavy soil.

(1) Moderate rains in early summer (August/September) are less effective than is usually supposed; no appreciable increase in moisture status occurs at a depth of more than 2 inches below the surface. A continuous precipitation of about 1 inch is necessary in order to penetrate to a depth of 9 inches. The smaller precipitations which suffice to produce significant improvement in moisture status after the initial wetting of the soil are discussed.

(2) The ability of a soil stratum to supply moisture to its surroundings approaches the state specified by the wilting coefficient when the conductivity reaches the *lentoconductivity*. The times required for soil strata at different depths and in

* i.e., at 1st Jan., $x=1$, 1st Feb., $x=32$, . . . 31st Dec., $x=365$.

different seasons of the year to dry to the extent indicated by the lentoconductivity level are examined.

(3) In summer, drying of strata within 8 inches of the surface occurs in about 1 week; at 20 inches below the surface, the time of drying increases to from 5 to 7 weeks. Summer failure of subsoil water is, therefore, a rare occurrence.

(4) In winter, drying of the upper strata is from 2 to 3 times slower than in summer. The winter periods for which the lower strata remain dry are tabulated and discussed.

(5) Capillary movement of water between the soil strata is inappreciable when the moisture status is below the lentoconductivity level; but it appears likely that in the subsoil the date at which a given stratum becomes dry can be predicted from a knowledge of the date at which the stratum immediately below it was wetted by direct penetration.

ACKNOWLEDGMENTS.

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TABLE IV.

Number of days, from date of last direct penetration, for different strata to reach their lentoconductivity levels. Bracketed figures refer to cases of partial wetting.

AB	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1939 ...	—	—	—	—	—	26	—	—	7	9	7, 7	(3), 8
1940 ...	6, 3	6, 6	7, 11	8, (5)	15	—	24	—	—	(4), 5. (2)	7	6
1941 ...	7, 6	6	9	10, 13	—	—	—	—	—	—	—	—
1942 ...	5	5, 6	9	—	—	—	—	—	6	5	5	7, 6
1943 ...	8, 6	10, 7	5	5, 7	—	21, 15	18	—	—	—	—	—
BC												
1939 ...	—	—	—	—	—	29	—	—	7	9	9, 7	8
1940 ...	6, 2	6, 5	7, 10	8	15	13	—	—	—	(4), (3)	4	5
1941 ...	8, 6	6	9	10, 12	—	—	—	—	—	—	—	—
1942 ...	5	5, 5	—	—	—	—	—	—	—	6	5	6, 5
1943 ...	6, 6	6, 6	6	4, 7	—	20, 12	15	—	—	—	—	—
CD												
1939 ...	—	—	—	—	—	26	—	—	9	—	12, (7)	—
1940 ...	14, (5)	7	9, 16	11	13	—	25	—	—	—	7	8
1941 ...	12, (3)	6	9	10, 11	—	—	—	—	—	—	—	—
1942 ...	5	5	10	—	—	—	—	—	—	—	8	8, 6
1943 ...	10, 7	9	12, 7	—	—	20, 13	18	—	—	—	—	—
DE												
1939 ...	—	—	—	61	—	59	—	—	—	14	49	—
1940 ...	31	28	22	46	44	—	82	—	—	—	30	—
1941 ...	25	16	15	16, 21	—	—	—	—	—	—	—	—
1942 ...	—	14	—	31	—	—	—	—	—	—	—	—
1943 ...	29	24	35	—	—	—	—	—	—	—	—	—
EF												
1939 ...	—	—	—	64	—	59	—	—	—	18	48	—
1940 ...	23	23	24	44	44	—	77	—	—	—	30	—
1941 ...	26	16	(12)	11, 19	—	—	—	—	—	—	—	—
1942 ...	—	18	—	43	—	—	—	—	—	—	—	—
1943 ...	27	22	33	—	—	—	—	—	—	—	—	—

TABLE IV—(continued).

FG		Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec
1939	...	—	—	—	38	—	32	—	—	—	—	33	—
1940	...	20	18	10	40	27	—	43	—	—	—	26	—
1941	...	17	—	—	—	—	—	—	—	—	—	—	—
1942	...	—	18	—	31	—	—	—	—	—	—	18	—
1943	...	20	12	14	—	—	—	—	—	—	—	—	—
GH													
1939	...	35	—	—	38	—	24	—	—	—	—	37	—
1940	...	(18)	21	—	34	31	—	53	—	—	—	32	—
1941	...	18	—	—	—	—	—	—	—	—	—	—	—
1942	...	—	17	—	31	—	—	—	—	—	—	19	—
1943	...	20	(8)	15	—	—	—	—	—	—	—	—	—
HI													
1939	...	44	—	—	63	—	42	—	—	—	—	49	—
1940	...	29	22	—	42	—	56	—	101	—	—	37	—
1941	...	46	—	—	—	—	—	—	—	—	—	—	—
1912	...	—	—	—	57	—	—	—	—	—	—	24	—
1943	...	39	—	—	—	—	—	—	—	—	—	—	—
IJ													
1939	...	41	—	—	59	—	51	—	—	—	—	49	—
1940	...	—	—	—	30	—	57	—	101	—	—	46	—
1941	...	48	—	—	—	—	—	—	—	—	—	—	—
1942	...	—	—	—	59	—	—	—	—	—	—	—	—
1943	...	57	—	—	—	—	—	—	—	—	—	—	
JK													
1939	...	—	—	—	42	—	48	—	—	—	—	—	60
1940	...	—	—	—	—	—	74	—	102	—	—	—	—
1941	. .	54	—	—	—	—	—	—	—	—	—	—	—
1942	...	—	—	—	—	—	145	—	—	—	—	—	—
1943	...	—	82	—	—	—	—	—	—	—	—	—	—
KL													
1939	...	—	—	....	60	—	—	—	—	—	—	—	81
1940	...	—	—	—	55	—	84	—	111	—	—	—	—
1941	...	—	60	—	—	—	—	—	—	—	—	—	—
1942	...	—	—	—	—	—	—	206	—	—	—	—	—
1943	...	—	—	—	—	—	—	—	—	—	—	—	—

TABLE V.

Periods for which conductivities in lower strata lay below their lentoconductivity values.

	DE	EF	FG	GH	HI	IJ	JK	KL	To
	From								
1939	—	—	22/4/39	19/4/39	15/4/39	—	—	—	20/ 5/39
	18/7/39	12/7/39	20/6/39	17/6/39	30/6/39	—	—	—	25/ 9/39
	—	—	—	—	—	11/5/39	16/5/39	9/ 5/39	6/10/39
1940	—	—	27/4/40	24/4/40	4/5/40	1/5/40	—	—	5/ 5/40
	18/6/40	—	1/6/40	4/6/40	—	—	—	—	19/ 6/40
	—	9/9/40	2/8/40	11/8/40	26/8/40	29/9/40	29/9/40	29/ 9/40	9/11/40
1941	17/5/41	8/5/41	17/3/41	16/3/41	20/3/41	17/3/41	14/3/41	30/ 3/41	7/ 1/42
1942	24/4/42	11/5/42	19/4/42	16/4/42	14/5/42	18/5/42	10/8/42	20/10/42	28/10/42
1943	—	5/4/43	20/3/43	21/3/43	30/3/43	25/3/43	—	—	15/ 4/43

TABLE VI.

Mean lentoconductivities, λ, with their probable errors* derived from n observations.

	AB	BC	CD	DE	EF	FG	GH	HI	IJ	JK	KL
n ...	11	12	11	5	5	10	9	7	7	6	6
λ ...	2·6±0·2	2·7±0·2	3·2±0·2	3·8±0·1	3·7±0·1*	3·1±0·2	3·3±0·2	3·9±0·2	4·3±0·2	4·2±0·1	4·5±0·1

* In this table, and in Table VII, probable error of mean of n observations $= 0{\cdot}6745 \sqrt{\dfrac{\Sigma\,[\text{deviations from mean}]^2}{n\ (n-1)}}$

TABLE VII.

Mean number of days D for various strata to dry (to their lentoconductivity levels), with probable errors of the means derived from n observations.

	AB	BC	CD	DE	EF	FG	GH	HI	IJ
Mean depth below surface (inches)	2·75	3·9	6·2	8·4	9·05	11·3	14·1	15·55	19·95
Summer Months:									
n	27	25	16	10	10	9	8	8	5
D	6·4±0·2	6·0±0·2	8·3±0·4	26·0±2·2	25·1±2·0	20·2±1·4	24·9±2·0	36·3±2·4	48·2±1·8
Winter Months									
n	6	6	6	—	—	—	—	—	—
D	20·3±1·4	17·3±1·7	17·5±2·0	—	—	—	—	—	—

TABLE VIII.

Time of drying of stratum JK (to lentoconductivity level), observed and calculated from equation $y = 1{\cdot}24\ x + 70$.

	x	y (calc.)	y (obs.)		x	y (calc.)	y (obs.)
1939	55	138	136	1941	2	73	73
1940	141	245	243	[1942 ...	78	167	222]

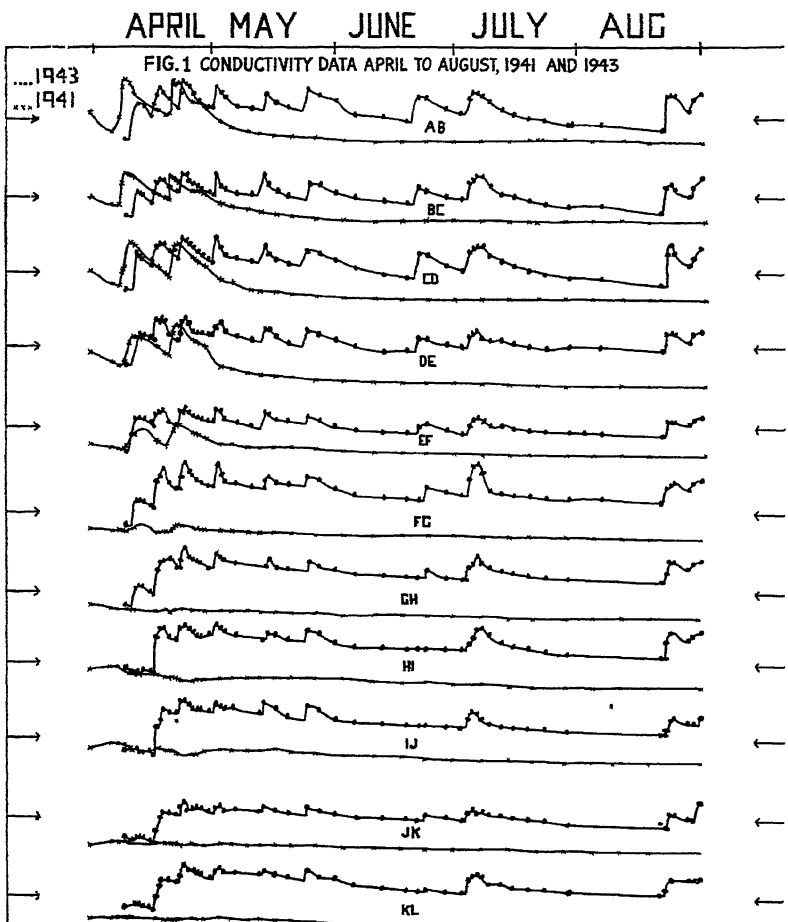

FIG. 1 CONDUCTIVITY DATA APRIL TO AUGUST, 1941 AND 1943

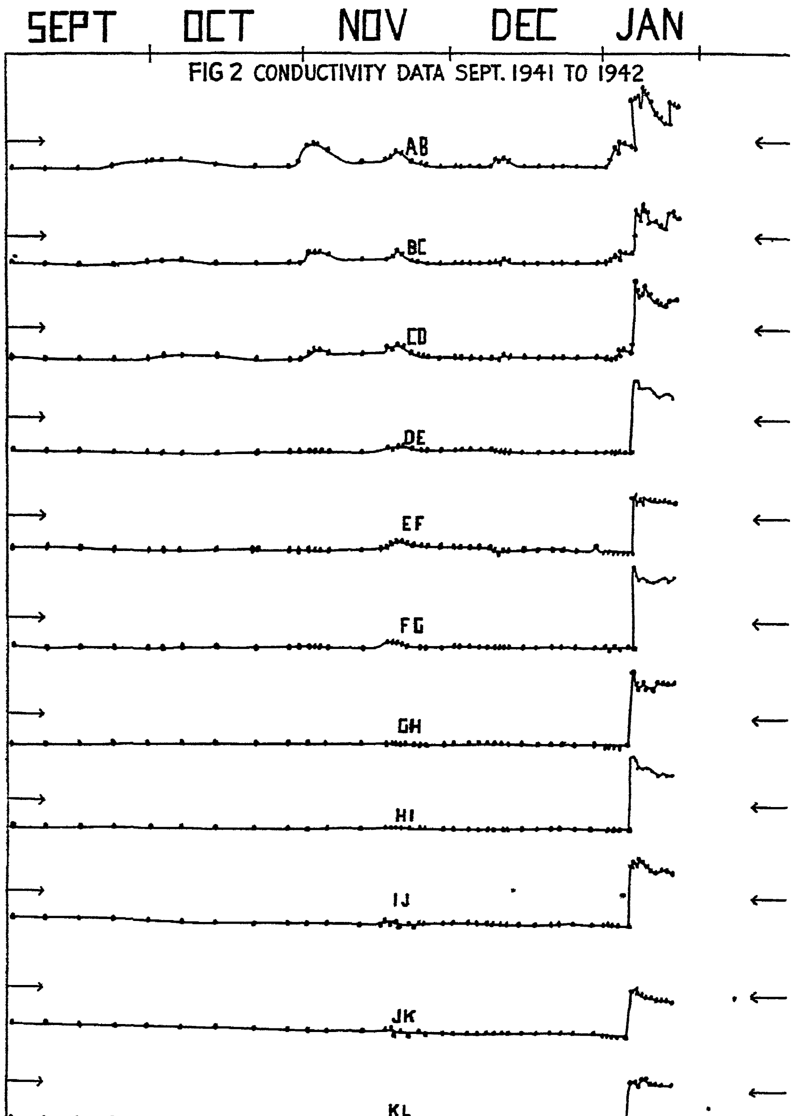

FIG 2 CONDUCTIVITY DATA SEPT. 1941 TO 1942

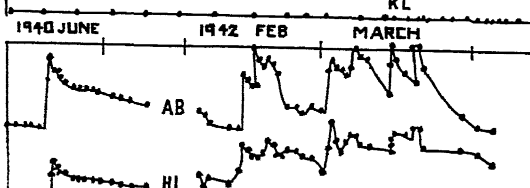

FIG 3 CONDUCTIVITY DATA FOR ELECTRIC PAIR AB AND HI FOR ABOVE PERIODS

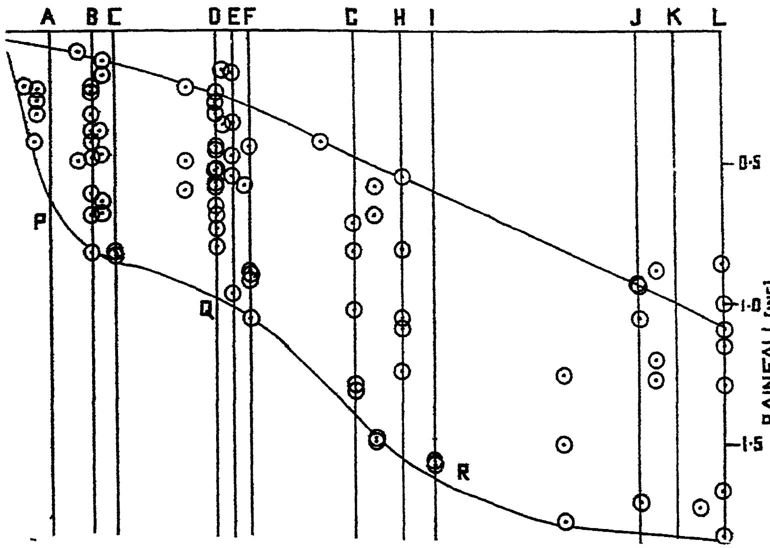

Fig. 4 Rainfall required to penetrate to depth specified by various Electrodes (Table I)

THE UPTHRUST AND CONTINUAL ENGINES

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THE QUANTUM ROTATIONAL ANALYSIS OF THE BAND SPECTRUM OF THE SULPHUR MOLECULE, S_2

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With 3 Text Figures.

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Part I—Introduction.

The vibrational structure of the S_2 bands lying between λ2400 and 6200 A has been studied by several investigators, such as Rosen (1927:69), Christy and Naudé (1931:903) and Fowler and Vaidya (1931:310). Christy and Naudé found that the vibrational differences of the upper state of the S_2 molecule, $\Delta G'$, were perturbed instead of decreasing regularly as $\Delta G''$, the vibrational differences of the lower state. (See Table I.) This result was confirmed by Fowler and Vaidya, who succeeded in obtaining a more complete vibrational analysis of the S_2 bands by studying the flame spectrum of CS_2, and from whose work Table I has been extracted.

Table I.

$\Delta G'$ and $\Delta G''$ Values of the S_2 Bands.

$v' =$	0	1	2	3	4	5	6	7	8	9	10
$\Delta G' =$	447	415	433	397	417	388	402	391	383	379	
$v'' =$	0	1	2	3	4	5	6	7	8	9	10
$\Delta G'' =$	723	715	705	704	699	691	683	677	674	669	663
$v'' =$	11	12	13	14	15	16	17	18	19	20	
$\Delta G'' =$	659	648	643	638	634	629	625	619	612	605	
$v'' =$	21	22	23	24	25	26	27	28	29	30	
$\Delta G'' =$	600	595	594	584	578	571	567	560	554		

Note.—The table must be read as follows: $\Delta G'$ between the $v' = 0$ and $v' = 1$ vibrational levels is 447 cm^{-1}, and $\Delta G''$ between the $v'' = 10$ and $v'' = 11$ vibrational levels is 663 cm^{-1}, etc.

This irregular behaviour of the $\Delta G'$ values of the S_2 molecule no doubt complicates the rotational structure of the bands considerably. Olsson (1936:656), however, seemed to have suc-

ceeded in obtaining a satisfactory rotational analysis of the (3, 2), (2, 2), (3, 3), (2, 3), (1, 3), (2, 4) and (1, 4) S_2 bands in absorption.

It is impossible to determine the effect which the observed perturbations in the $\Delta G'$ values have on the rotational analysis accurately in absorption, for it is impossible to analyse the band structure close to the band heads in this case. Hence it appeared that it would be of great value if a rotational analysis of the S_2 bands could be carried out in emission. The present rotational analysis was therefore started with this purpose. The vibrational analysis of Fowler and Vaidya and the rotational analysis of Olsson could also be verified simultaneously.

Naudé and Christy (1931:490) attempted to procure a rotational analysis of the S_2 bands lying at λ2857·36, 2860·13, 2887·84, 2917·38 and 2920·28 A in emission. After the experience obtained in the present analysis, it is clear that the resolving power obtained for these bands in the second order of the 21-foot grating on the old Rowland mounting at the University of Chicago was insufficient, and that the method of computing the approximate wave-numbers of the band series according to the rotational theory of band spectra which was used with success by Christy (1929:701) in the analysis of the TiO bands did not lead to a unique solution in the case of the S_2 bands. This may also have been due to the perturbations in the $\Delta G'$ values and the great amount of overlapping of the rotational lines from adjacent bands.

The present analysis was, therefore, started in a region where there was less overlapping and with the highest resolving power attainable by photographing in the fourth order of our 21-foot concave grating. At the same time bands were selected for analysis which had their upper vibrational states with $v' = 1$, 2 and 3 in common with the bands analysed by Olsson in absorption. In this way Olsson's analysis could be tested simultaneously.

PART II—EXPERIMENTAL PROCEDURE.

The S_2 spectrum was obtained by means of the tube indicated in Figure I. The sulphur was purified by slowly redistilling pure flower of sulphur four times in vacuo from one pyrex vessel to the next by means of an electrical oven. The vessel S in Figure I was the final recipient of the redistilled sulphur. S was sealed on to the pyrex capillary tube through which the electric discharge between the two upright aluminium electrodes took place. The light from the capillary tube passed through a quartz tube K with a clear quartz window sealed on to the quartz tube. The quartz tube was sealed on to the pyrex discharge tube by the special white sealing wax obtained from

the firm Lilliendahl, Neudietendorf, Thuringia. The quartz window could be kept clear by constantly heating it with a small gas flame.

The discharge through the tube was started as follows: The two electrodes were connected to the high voltage terminals of a 5-KVA. 220- to 12,000-volt step-up transformer. The tube was evacuated to about 10^{-5} mm. Hg pressure by means of a two-stage oil diffusion pump backed by a Cenco-Hyvac oil rotation pump. The sulphur in S was heated by an electric oven to about 170°C. The transformer was switched on intermittently. As soon as the sulphur pressure in the tube became high enough to maintain the discharge between the electrodes, an S_2 light source was obtained which was very intense in the capillary tube and which could be photographed end-on through the quartz window K.

The light produced by this light source was allowed to fall through the slot S (see Figure 2) and on to the new 21-foot concave grating ruled by Prof. H. Gale of Chicago University and mounted according to Paschen in a special dark room on a circle with radius equal to half the radius of curvature of the concave grating. The circle was mounted on concrete pillars with foundations about 3 feet below ground level and with cork layers of 4-inch thickness built into the pillars to insulate the circle against external vibrations. A concrete circle joins the pillars together. The upper surface of this circle is about 3 feet 4 inches above ground level. Steel plates were bolted down on the concrete circle. The upper surfaces of these steel plates were carefully adjusted by means of a theodolite to be on the same level. On the steel plates massive bronze brackets were bolted down which had been cast in the form of a " G " on a broad base. The base, the cross bar and the lower edge of the top curl which was also flattened out in the casting were machined down to be plane parallel and equidistant in all sixteen brackets. Thirty right-angled aluminium girders were cast with a radius of curvature of 10·5 feet, a length of 3 feet and the two sides forming the right angle 3 inches wide. They were machined at their ends. These ends were bolted with one side either to the cross bar or to the upper end of the G bracket and the other side of the right angle facing up or down respectively in the same vertical, curved surface, and with their free ends about 1·6 inches apart.

A counter poised steel arm was then pivoted on a concrete pillar in the centre of the circle. This steel arm was about 10·8 feet in length and could be rotated around the pivot in a horizontal plane which passed through the middle of the opening between the aluminium girders. A metal cutter which was about 2·1 inches in length and was sharpened at both ends, was mounted at a point on the steel arm which was exactly half the

distance of the radius of curvature of the concave grating from the pivot of the arm. The radius of curvature of the grating had previously been determined very accurately by Dr. P. de Vos of our department by means of Foucault's knife edge test. By rotating the steel arm, grooves, which had a radius of curvature equal to half the radius of curvature of the concave grating, were cut on the back sides of the Al girders. The upper and lower edges of the grooves were about 2·1 inches apart and could therefore serve as a plateholder for 2-inch wide photographic plates which were slightly bent to follow the curvature of the Al girders and were kept in position by specially provided spring clamps.

By means of a Gauss eyepiece mounted with the cross hairs in the plane of the circular groove, the grating was set up with its normal axis passing through the centre of the circle. By moving the grating backwards and forwards horizontally on a specially machined mounting, the position of the grating was obtained for which the cross wires of the Gauss eyepiece and their image reflected by the grating, coincided. In accordance with the theory of the concave grating the whole circular groove was found to be in focus for light passing through the slit which was also mounted accurately on the circular groove. The mounting of the grating and the building of all the mechanical parts were carried out with great skill by our mechanic, Mr. K. Gürgen.

Eastman Kodak No. 33 photographic plates were used for all the bands except the (3, 19) band, which was photographed on Eastman IIIF plates. The plates were 2 inches by 18 inches in size and were only about 1/30-inch thick, so that they could be bent to fit the circular groove without danger of breaking or becoming deformed. A half-minute exposure with an iron arc comparison spectrum was taken while one-half of the plate was covered by a metal strip fixed to the circle. A corning glass Noviol A No. 038 filter which cut off all light below 4200 A, was then placed in front of the slit to avoid the overlapping of the orders. The metal strips covering half of the plates were removed and photographs of the spectra of the (1, 14) band with its head at 4433·6 A, (1, 15) at 4563·2 A, (2, 16) at 4610·0 A, (3, 17) at 4651·3 A, (2, 17) at 4747·6 A, (3, 18) at 4790·8 A, and (3, 19) at 4937·2 A were taken simultaneously in the third and fourth orders of the grating. The exposure time required for all the bands except the (3, 19) band was about 2 hours with a current of 18 amps. passing through the primary of the transformer. The (3, 19) band required an exposure of about 20 hours.

The plates were measured out on a large Abbe type comparator built in our workshop by Mr. K. Gürgen. The calibrated millimetre glass scale and the special spiral type

measuring microscope were procured from Messrs. C. Zeiss, Jena. With this microscope it is possible to estimate accurately readings up to 0·0001 mm. on the scale, but the readings of the lines of the spectrum could usually only be measured accurately to 0·001 mm. in the case of sharp lines. This corresponds to an accuracy of under 0·001 A in the fourth order since the dispersion of the grating in this order amounted to about 0·57 A per mm. Since 1 mm. corresponds to about 2·5 cm^{-1} in the region investigated, the accuracy attainable for the wave-numbers of the spectrum lines amounted to about 0·003 cm^{-1}. An accuracy of 0·01 cm^{-1} was assumed in the analysis for sharp lines and further decimals were dropped. In the case of broad, fuzzy lines or double lines the error may be as much as 0·05 cm^{-1}. As is well known, this accuracy holds only for the difference between lines and not for the absolute wave-numbers of the lines. These wave-numbers were found to differ by as much as 0·05 cm^{-1} from plate to plate for the same line. The difference is due to a very slight shift of the comparison spectrum from plate to plate. Since the analysis is based on wave-number differences this shift does not affect the accuracy of the analysis.

The wave-lengths of the iron arc lines used as comparison spectrum were obtained from Harrison's " M.I.T. Wave-length Tables " (1939).

The wave-numbers of the band lines were calculated by the following method used with success by the author (1932:117). For every band three suitable iron lines were chosen as wave-length standards. A third order equation was passed through these standards. The accuracy of the equation was tested by comparing the calculated wave-lengths of the iron lines which lie between these standards with the wave-lengths given in Harrison's Tables. If the agreement was good the equation was used to calculate the wave-lengths of imaginary points 1 mm. apart on the plate. These wave-lengths were converted to wave-numbers in vacuo by using Kayser's " Tabelle der Schwingungs-zahlen " (1925). The dispersion in wave-numbers for each mm. interval was known now and the wave-numbers of the lines lying in these mm. intervals were computed by interpolation on a Marchant Model CT10M calculating machine for ten digit numbers.

The resolving power obtained in the fourth order of the grating was about 300,000. which is about 75 per cent. of the value expected from a ruled surface of 5·5 inches with 18,000 lines per inch. Even with this high resolving power some lines could not be resolved.

PART III—DATA AND THE STRUCTURE OF THE BANDS.

The S_2 bands are degraded towards the red. Under high dispersion it appears as if the bands have one strong head and

another weaker head lying about 7 or 8 cm^{-1} to the violet of the strong head, but in certain perturbed bands, such as (2, 16) and (2, 17), it appears as if the weak head lies about 31 cm^{-1} to the violet of the strong head. Under low dispersion the strong heads are most conspicuous and are usually measured as the band heads which are used for the vibrational analysis.

Practically all the lines of the (1, 14), (1, 15), (3, 17), (3, 18) and (3, 19) bands could be accounted for by six branches. Most of the stronger lines of the (2, 16) and (2, 17) bands lying further than about 25 cm^{-1} from the heads could also be arranged in six branches. The six branches were further found to correspond to three R and three P branches, which agrees with what one would expect for a $^3\Sigma \longrightarrow {}^3\Sigma$ transition. The assignment of the R and P branches as R_1, R_2, R_3, P_1, P_2 and P_3 branches will be discussed later.

These results agree with Olsson's analysis and are in accordance with what one would expect if the S_2 bands were analogous to the Schumann-Runge bands of O_2 analysed by Ossenbrüggen (1928:167) and Lochte-Holtgreven and Dieke (1929:937).

Tables 2, 3, 4, 5, 6, 7 and 8 give respectively the wave-numbers of the branches into which the (1, 14), (1, 15), (2, 16), (2, 17), (3, 17), (3, 18) and (3, 19) bands could be analysed. The quantum number K, corresponding to the lines belonging to the six branches, is given in the first column. The number in brackets behind each wave-number gives the visual estimation of the intensity of the line on the photographic plate. An *f* or a *d* behind this number indicates respectively a broad, fuzzy or a double line which could not be resolved. The superscript outside the bracketed number gives the number of lines to which the same wave-number was ascribed if more than one. It will be noticed that some branches of the (2, 16) and (2, 17) bands could not be followed to the smaller K values. This is probably due to the abovementioned perturbations in the $\Delta G'$ values and will be the subject of further study.

The rotational levels of a $^3\Sigma$ state are given by

$$F_i = B_v K(K+1) + f_i(K, J-K) + L_v K^2 (K+1)^2 + \ldots \quad (1)$$

where J represents the total angular momentum of the molecule, its values being $J = (K+S), (K+S-1), \ldots (K-S)$. S is the resultant electronic spin. For a triplet $S=1$, hence $J = (K+1)$, K and $(K-1)$. Due to the three values of J we should get three closely spaced energy states for each value of K. These energy states are designated by F_1, F_2 and F_3 where F_1 corresponds to $J=K+1$, F_2, to $J=K$, and F_3 to $J=K-1$. For fuller particulars see Mulliken (1930:106).

Kramers (1929:422) showed that for $^3\Sigma$ states $f_i(K, J-K)$ is made up of two parts, one of which is due to the interaction

of the resultant electronic spin $\mathbf{S}^*$ with the rotational angular momentum $\mathbf{K}^*$ and is equal to

$$\tfrac{1}{2}\gamma\,[J\,(J+1) - K\,(K+1) - S\,(S+1)] = \tfrac{1}{2}\gamma\,[J\,(J+1) - K\,(K+1) - 2] \quad . \; . \; . \quad (2)$$

while the other part is due to the interaction between the individual spins of the electrons and is designated by $w_i\,(K, J-K)$. $f_i\,(K, J-K)$ thus becomes

$$f_i\,(K, J-K) = \tfrac{1}{2}\gamma\,[J\,(J+1) - K\,(K+1) - 2] + w_i\,(K, J-K) \quad . \; . \; . \; . \; . \; . \; . \; . \quad (3)$$

Kramers further showed that $w_i\,(K, J-K)$ had the following forms for the three values of J:—

$$\text{for } J = K+1, \quad w_1 = -\varepsilon\,[1-3/(2K+3)] \quad . \; . \; . \; . \; . \; . \; . \quad (4)$$

$$J = K-1, \quad w_3 = -\varepsilon\,[1+3/(2K-1)] \quad . \; . \; . \; . \; . \; . \; . \quad (5)$$

$$J = K \;\;, \quad w_2 = +2 \quad . \; . \; . \; . \; . \; . \; . \quad (6)$$

Combining Equations (3), (4), (5) and (6) we get:—

$$\text{for } J = K+1, \quad f_1 = -\varepsilon[1-3/(2K+3)] + \gamma K \quad . \; . \; . \quad (7)$$

$$J = K-1, \quad f_3 = -\varepsilon\,[1-3/(2K-1)] - \gamma\,(K+1) \quad . \quad (8)$$

$$J = K \;\;, \quad f_2 = 2\,\varepsilon - \gamma \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (9)$$

Now

$$\Delta_2 F_1^{(1)}(K) = R_1(K) - P_1(K) = F_1^{(1)}\,(K+1) - F_1^{(1)}\,(K-1) \quad (10)$$

Substituting in Equation (1) for f_i according to Equations (7), (8) and (9), and neglecting terms in ε/K for moderate and large values of K, since ε is usually small, it follows from Equation (10) that for

$$J = K+1, \; \Delta_2 F'_1(K) = 2(B'_v + 2D'_v+\gamma) + 4\,(B'_v+3D'_v)K + 12D'_vK^2 + 8D'_vK^3 \quad . \; . \; . \; . \; . \; . \; . \quad (11)$$

$$J = K-1, \; \Delta_2 F'_3(K) = 2(B'_v + 2D'_v-\gamma) + 4\,(B'_v+3D'_v)K + 12D'_vK^2 + 8D'_vK^3 \quad . \; . \; . \; . \; . \; . \; . \quad (12)$$

$$J = K, \; \Delta_2 F'_2(K) = 2(B'_v + 2D'_v) + 4\,(B'_v+3D'_v)K + 12D'_vK^2 + 8D'_vK^3 \quad . \; . \; . \; . \; . \; . \; . \quad (13)$$

For the lower electronic state

$$\Delta_2 F''_1(K) = R_1(K+1) - P_1(K-1) = F''_1(K+1) - F''_1(K-1) \quad . \; . \; . \; . \quad (14)$$

has exactly the same form as in the above equation except that (′) must be replaced by (″).

In Tables 9, 10 and 11 the $\Delta_2 F'_1(K)$, $\Delta_2 F'_2(K)$ and $\Delta_2 F'_3(K)$ values of the $v' = 1$, 2 and 3 vibrational states respectively are given which agree within experimental error as required if the above analysis into branches is correct. In Table 12 the $\Delta_2 F''_1(K)$, $\Delta_2 F''_2(K)$ and $\Delta_2 F''_3(K)$ for the $v'' = 17$ level are

compared and are found to agree within experimental error. The mutual agreement of the combinations and the agreement with Olsson's values which were computed from the branches listed by him for the (1, 3), (1, 4), (2, 2), (2, 3), (2, 4), (3, 2) and (3, 3) bands and averaged for the $v' = 1$, 2 and 3 states, verifies the correctness of the above rotational analysis of the S_2 bands. At the same time the vibrational analysis of the S_2 bands by Fowler and Vaidya is proved to be correct.

The assignment of the R_1 and P_1 branches as R_1, R_2, R_3 and P_1, P_2 and P_3 branches respectively was carried out with the help of Equations (7), (8) and (9) by a graphical method similar to that used by Olsson (1936:658). Seeing that the results obtained here agree with the conclusions drawn by Olsson, no further description of the method will be given.

Part IV—The Molecular Constants and the Determination of the K Values.

From Equations (1), (9) and (10) we get:—

$$\begin{aligned}\Delta_2F'_2(K) &= F'_2(K+1) - F'_2(K-1)\\ &= B'_v(K+1)(K+2) + D'_v(K+1)^2(K+2)^2 - B'_v(K-1)K - D'_v(K-1)^2K^2\\ &= 4\,B'_v(K+\tfrac{1}{2}) + 8\,D'_v(K+\tfrac{1}{2})^3 \qquad \ldots\ldots \quad (15)\end{aligned}$$

Equation (9) is chosen here for according to it f_2 is independent of K and henee f_2 disappears completely in $\Delta_2F'_2(K)$. Since D'_v is usually very small compared with B'_v, the term with D'_v can be neglected for small and moderate values of K. A similar formula holds for $\Delta_2F''_2(K)$.

The $\Delta_2F'_2(K)$ values of Tables 9, 10 and 11 and the $\Delta_2F''_2(K)$ values of Table 12 can now be plotted against K. From the slope of the curves B'_v for the vibrational levels $v'=1$, 2 and 3, and B''_v for the vibrational level $v''=17$ can be determined. From Tables 2, 3, 4, 7 and 8 the $\Delta_2F''_2(K)$ values for the vibrational levels $v''=14$, 15, 16, 18 and 19 can also be computed, and from these values the corresponding B''_v values can be determined graphically as above. As will be seen below, alternate lines of the branches are missing, and hence the slope obtained graphically must be divided by 8 to obtain the correct B_v. These values of B'_v and B''_v are listed in Table 13 together with the B'_v values of the $v'=4$, 5, 6 and 7 and the B''_v values of the $v''=22$, 23, 24, 25 and 27 vibrational levels obtained from the unpublished analysis of the (4, 19), (4, 22), (5, 22), (5, 23), (6, 23), 6, 24), (7, 25) and (7, 27) bands by the author.

In Table 13 the B'_8, B'_7 and B''_0 values are also included. These values were obtained from an unpublished M.A. thesis of Wilson (1941:50), an extract of which was kindly submitted to the author by Prof. G. Herzberg of the Department of Physics, University of Saskatchewan, Saskatoon, Canada.

The B''_4, B''_3 and B''_2 listed were obtained by Olsson (1936:659). The values of B'_3, B'_2 and B'_1 given by Olsson are 0·2146, 0·2174 and 0·2173 cm^{-1}. The B'_1 value found by Olsson differed greatly from the value found by the author. Olsson's $\Delta_2F'_2(K)$ values for the $v'=3$, 2 and 1 vibrational states were replotted by the author and are given in Table 13.

B_e, α_e and r_e can be determined with the help of the following equations:—

$$\alpha_e = (B_0 - B_v)/v$$

$$B_e = B_0 + \tfrac{1}{2}\alpha_e$$

$$r_e^2 = \frac{27{\cdot}994 \times 10^{-40}}{\mu B_e} \text{ where } \frac{1}{\mu} = \frac{1}{32{\cdot}06} + \frac{1}{32{\cdot}06}$$

and where the atomic weight of the more abundant isotope of sulphur is taken as 32·06. μ is multiplied by $1{\cdot}649 \times 10^{-24}$ to reduce the atomic weight to mass in grams.

D_e was computed from the equation: $D_e = -4\, B^3_e/\omega^2_e$.

According to Wilson, $\omega''_e = 725{\cdot}68 \pm 0{\cdot}01$ cm^{-1}. Owing to the perturbations in the upper state it is impossible to estimate ω'_e accurately. According to the analysis of Fowler and Vaidya we may take $\omega'_e = 435$ cm^{-1} approximately.

The exact values of the rotational quantum numbers K were also obtained from the above graphs by extrapolating the straight curves representing Equation (15) to $\Delta_2F'_2(K)=0$. If the K values are assigned correctly, the straight line cuts the K axis at $K = -\tfrac{1}{2}$. This was found to be the case for every band, and hence the K values are correct. It was now found that the rotational levels with *even* K values were missing in the *lower state* and that those with *odd* K values were missing in the *upper state*. Since alternate levels are missing, we conclude that the internal angular momentum of the S^{32} nucleus is zero.

Exactly similar results were obtained from the Schumann-Runge bands of O_2 by Ossenbrüggen as well as Lochte-Holtgreven and Dieke. Mulliken (1930:700) showed that the lower state of O_2 was in all probability a ${}^3\Sigma^-_g$ state. Hence we conclude that the analogous S_2 bands investigated here are due to a ${}^3\Sigma^-_u \longrightarrow {}^3\Sigma^-_g$ transition. Figure 3 gives a schematic representation of the rotational energy levels of S_2.

Part V—Discussion of the Results and Conclusion.

From Tables 9, 10, 11 and 12 it is seen that the band branches could be extended to lower and higher quantum numbers in the present analysis in emission than was possible in Olsson's analysis in absorption. From the computed $\Delta_2F(K)$ values extracted from Olsson's paper it further became clear that the mutual agreement of these values for the same vibrational states was much better here than in Olsson's paper. This is due, no

doubt, to the greater accuracy with which the rotational lines can be measured in emission than in absorption.

A remarkable aspect of the analysis is that the branches of the (2, 16) and the (2, 17) bands could not be extended to the smaller K values, although the combinations for the $v''=17$ state were known from the analysis of the (3, 17) band. This may be due to perturbations of the $v'=2$ vibrational state. In the (4, 19), (4, 22), (6, 23), (6, 24) and (6, 25) bands it has so far been impossible to find the R_3 and P_3 series. This may also be due to perturbations in the $v'=4$ and 6 vibrational states. It is intended to continue the research on the S_2 spectrum with the purpose of studying the above perturbations as well as their causes.

SUMMARY.

The emission spectrum of S_2 has been obtained by means of a Geissler tube, the plates being taken in the fourth order of a 21-foot concave grating with a dispersion of about 0·57 A per mm. The following bands have been analysed: (1, 14) at λ4433·6 A, (1, 15) at 4563·2 A, (2, 16) at 4610·0 A, (2, 17) at 4747·6 A, (3, 17) at 4651·3 A, (3, 18) at 4790·8 A and (3, 19) at 4937·2 A. Each band consists of three R and three P branches. The structure was found to be similar to that of the Schumann-Runge bands of O_2. It is concluded that the S_2 bands are due to a ${}^3\Sigma^-_u \longrightarrow {}^3\Sigma^-_g$ transition. The values of B'_e and B''_e were found to be 0·2219 and 0·2956 cm^{-1} respectively and the nuclear separation of the upper state $r'_e = 2{\cdot}184 \times 10^{-8}$ cm and of the lower state $r''_e = 1{\cdot}893 \times 10^{-8}$ cm. It was found that the levels with *odd* K values are missing in the *upper state* and those with *even* K values in the *lower state*. From the fact that the alternate rotational levels are missing it is concluded that the internal angular momentum of the S^{32} nucleus is zero.

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Figure 1—The Pyrex Discharge Tube.

Figure 2—The Paschen Mounting of the 21ft. concave grating. S represents the slit and G the concave grating. Both S and G are mounted on the circle with radius 10·5 feet. The marks on the circle give approximately the positions at which the wave-length 5000 A will be observed in the first, second, third and fourth orders of the grating. The double door allows one to enter the room without spoiling the photographic plates exposed on the circle.

Figure 3—A schematic representation of the structure of the rotational energy levels of S_2. The groups with rotational quantum numbers K+1 and K−1 refer to the upper $^3\Sigma^-_u$ state, and the group with quantum number K to the lower $^3\Sigma^-_g$ normal state. The dotted line represents the position of the rotational level if no interaction between *K* and *S* existed, its approximate energy value being given directly above it. The full lines represent the actual levels resulting from the interaction of the resultant electronic spin *S** with the rotational angular momentum *K** and the interaction between the individual spins of the electrons. The calculated separation of these levels from the dotted line is given on the right. The lines joining the upper and the lower levels represent the observed transitions and are named accordingly. The K in the diagram represents the value of K″.

The Pyrex Discharge Tube.

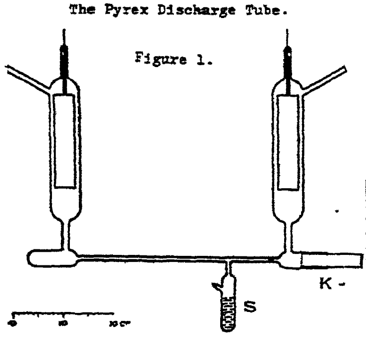

Figure 1.

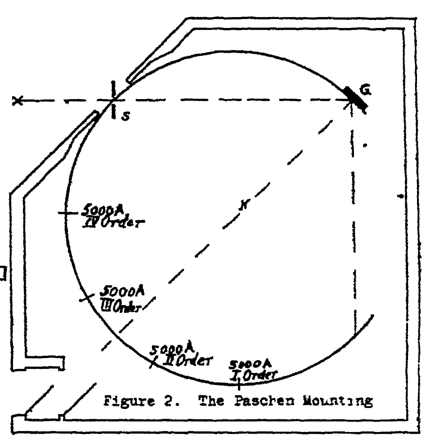

Figure 2. The Paschen Mounting

Figure 3.

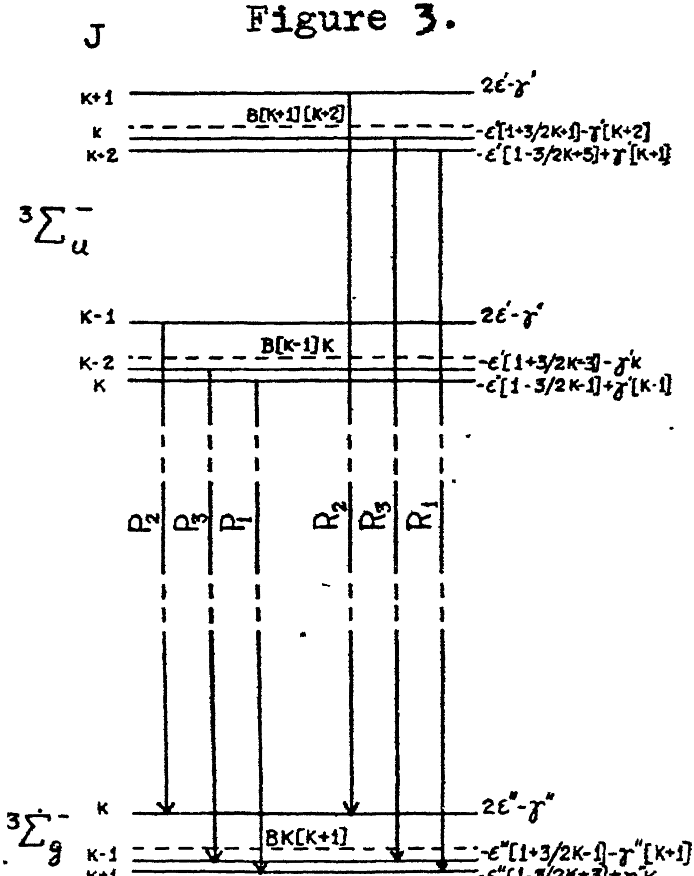
J
K+1
K
K+2
2ε'-γ'
-ε'[1+3/2K+1]-γ'[K+2]
-ε'[1-3/2K+5]+γ'[K+1]
B[K+1][K+2]
³Σu⁻
K-1
K-2
K
2ε'-γ'
-ε'[1+3/2K-3]-γ'K
-ε'[1-3/2K-1]+γ'[K-1]
B[K-1]K
P2
P3
P1
R2
R3
R1
³Σg⁻
K
K-1
K+1
2ε"-γ"
-ε"[1+3/2K-1]-γ"[K+1]
-ε"[1-3/2K+3]+γ"K
BK[K+1]

TABLE 2—Wave-Numbers of the Lines belonging to the (1, 14) Band.

K	R_1	R_2	R_3	P_1	P_2	P_3
1	22556·14(½)	—	—	22553 94(1)[2]	—	—
3	56·14(½)[2]	—	—	52 37(2)[2]	—	—
5	55 83(½)	22518·44(2f)	22518·96(0)	50·37(2)[2]	22513·57(0)	22514·43(1)
7	55·05(3f)	47·96(3)[5]	48·44(2f)[2]	17·96(3)[3]	41 30(½)	42·30(1)
9	53·91(1)	47·13(2)	47·62(0)	15·13(5)[2]	38·70(½)	39 81(½)
11	52·37(2)	45·80(2)	46·43(1)	41·93(4)	35 63(1f)	36·84(½)
13	50·37(2)	44·12(2)	44·80(1)	38 21(3)[2]	32 21(½)	33·40(2)
15	47·96(3)[1]	42·02(1)	42·69(2)	31 10(4)[2]	28·35(1)	29·54(10f)[5]
17	45 13(5)	39·51(1)	40·21(2)	29 54(10f)	24·05(1)	25 29(4)[2]
19	41 93(4)	36·58(2)	37·15(1)	24 61(6)[2]	19·31(2)	20·43(2)
21	38·21(3)	33·25(2)	33·62(2)	19·22(4)[2]	14·27(4)[2]	15·21(1)
23	34·10(1)[2]	29·54(10f)[5]	29·54(10f)[5]	13 38(2d)[2]	08·75(2)	09 48(1)
25	29 54(10f)[5]	25·29(4)[2]	25·07(2)	07·17(2)	02·82(1)	03·21(½d)
27	24·61(6)[2]	20·75(2)	19·93(2)	00·49(2)	22496·48(4)[2]	22496 48(4)[2]
29	19·22(4)[2]	15·78(3)	14·27(4)[2]	22493·40(2)	89·75(3)	89·20(1f)
31	13·38(2d)[2]	10·38(4)	08·01(1)	85·85(1)	82 58(4)	81·35(1)
33	06·96(2)	04·54(2)	01·08(2)	77·78(2)	75 02(1)	72 87(1)
35	00·19(1)	22498·28(1)	22493·51(2)	69 33(2)	67 04(3)	63·81(1)
37	22492 76(4)	91·55(3)	85·28(½1)	60 31(4)	58 61(2)	54·03(2)
39	84·94(1)	84·23(2)	76·40(1)	50 83(2)	49·72(4)	43 62(½)
41	76 60(1)	—	66·79(1)	40 84(1)	40·23(2)	32 47(½)
43	67·60(1)	—	56·57(½f)	30 30(1)[2]	30 30(1)[2]	—
45	58·04(1)	—	—	19 20(1)	—	—
47	47·84(1)	—	—	07·48(1)	—	—
49	37·01(½)	—	—	22395·16(1)	—	—
51	25·45(2)	—	—	82·16(½)	—	—
53	13·33(½f)	—	—	68·50(1)	—	—
—	—	—	—	54·13(½)	—	—
—	—	—	—	39·19(0)	—	—

TABLE 3—Wave-Numbers of the Lines belonging to the (1, 15) Band.

K	R_1	R_2	R_3	P_1	P_2	P_3
7	—	21907·20(½)^2	—	—	—	—
9	21913·78(0)	06·66(½f)	21908·58(2)	21905·05(0)	21898·25(3)^2	21900·85(0f)
11	12·29(1)	05·57(0)	07·20(½)^2	01·92(1)^2	95·43(½)	21897·63(2)
13	10·38(0)	03·96(1)	05·57(0)	21898·25(3)^2	91·95(2d)	94·10(3)
15	08·09(4)	01·92(1)^2	02·57(½f)	94·22(3)	88·22(½d)	89·45(1)
17	05·36(0)	21899·48(1)	00·18(½f)	89·77(3)	84·07(0)	85·25(½)
19	02·21(2)	96·69(1)	21897·27(½)	84·98(1)	79·51(1)	80·65(4f)^2
21	21898·69(1)	93·49(1)	93·92(1)	79·73(1)	74·52(2f)	75·48(3)
23	94·68(2f)	90·00(1)	89·97(3)	74·07(1)	69·16(3)^2	69·91(2)
25	90·39(2f)	85·89(1)	85·60(2)^2	67·96(2f)	63·41(2f)	63·86(3f)
27	85·00(2)^2	81·43(3f)	80·65(4f)^2	61·47(1)	57·23(4)^2	57·23(4)^2
29	80·35(2)	76·67(1)	75·26(1f)	54·56(2f)	50·70(1)	50·10(3)
31	74·66(2f)	71·49(1)	69·16(3)^2	47·14(5)^3	43·72(1)	42·50(4)
33	68·50(1)	65·88(2)	62·44(1)	39·32(1)	36·38(2)	34·21(1)
35	61·86(2f)	59·82(5)	55·11(1)	31·07(2)	28·61(2)	25·35(0)
37	54·77(1)	53·34(2)	47·14(5)^3	22·30(1)	20·39(3)	15·88(½)
39	47·14(5)^3	46·27(1)	38·45(1)	13·09(1)	11·75(2)	05·68(½)
41	39·05(1)	38·17(1)	29·09(1)	03·31(2)	02·55(1)	21794·85(½)
43	30·35(½)	29·70(0)	19·12(½)	21793·06(½)	21792·28(½)	83·41(0)
45	21·10(½f)	—	08·66(½)	82·24(½)	80·53(½)	71·93(1f)
47	11·18(3)	—	21797·19(0)	70·82(1f)	—	—
49	00·67(0)	—	—	58·81(0)	—	—
51	21789·44(0)	—	—	46·15(½)	—	—
53	77·59(½)	—	—	32·79(0)	—	—
55	65·12(0)	—	—	—	—	—

TABLE I.—Wave-Numbers of the Lines belonging to the (2, 16) Band.

K	R_1	R_2	R_3	P_1	P_2	P_3
7	—	21686·64(½)	—	—	21679·47(3)	—
9	—	85·80(1)	—	—	77·01(½f)	—
11	—	84·47(2)	—	—	74·15(1f)	—
13	—	82·74(1)	21692·85(1)	—	70·86(1)	21681·36(½f)
15	—	80·72(½)	91·13(1)	—	67·18(½)	77·82(1)[2]
17	—	78·39(0)	88·97(½)	—	63·09(1)	73·86(½)
19	—	75·59(½)	86·38(2)	—	58·56(½)	69·51(1)
21	—	72·33(2)[2]	83·37(1)	—	53·54(3)[2]	64·69(2f)
23	—	68·73(2)	79·89(2)	—	48·30(½)	59·45(2)
25	—	64·58(6f)	75·96(1)	—	42·42(3)	53·84(1)
27	—	60·06(5d)[2]	71·62(2)	—	36·11(4)[2]	47·76(1)
29	21677·82(1)[2]	55·04(4f)	66·80(2)	—	29·38(3)	41·22(2)
31	21672·33(2)[2]	49·75(5)[2]	61·55(3f)	21645·06(2f)	22·32(3)	34·27(2)
33	66·41(3)[2]	44·02(3)	55·92(2)	37·22(2f)	14·80(3d)[2]	26·86(1)
35	60·06(5d)[2]	37·91(3)	49·75(5)[2]	29·14(3)	06·99(3)	19·04(2)
37	53·54(3)[2]	31·37(4)[2]	43·13(3)	20·77(2)	21598·70(3)	10·72(2)
39	46·54(2)	24·34(2)	36·01(4)[2]	12·02(4)	90·02(4)	01·97(4)[2]
41	39·15(3)	16·91(2)	28·34(3)	02·94(2)	80·89(3)	21592·63(3)
43	31·37(4)[2]	08·99(3)	20·14(2f)	21593·47(4)	71·32(3)	82·87(2)
45	23·30(3)	00·63(3)	11·40(2)	83·60(3f)	61·28(2)	72·55(3)
47	14·80(3d)[2]	21591·74(4)	01·97(4)[2]	73·32(3)	50·73(4f)[2]	61·66(2)
49	05·78(2)	82·36(3)	21591·96(2)	62·66(2)	39·77(2)	50·12(1)
51	21596·43(2f)	72·42(4)	81·14(½)	51·59(2)	28·19(5)[2]	37·93(1)
53	86·63(2)	61·85(2)	69·54(½)	40·10(2)	16·17(2)	24·95(2)
55	76·39(3)	50·73(4f)[2]	57·06(1)	28·19(5)[2]	03·48(5)	11·23(½)
57	65·71(2)	38·77(1)	—	15·86(2)	21490·18(4f)[3]	21496·62(1)
59	54·54(1)	26·12(1)	—	03·07(2)	76·10(4)[2]	—
61	42·85(4)	12·78(½)	—	21489·80(3)[2]	61·40(6)[3]	—
63	30·47(2)	21498·53(0)	—	75·96(1)[3]	45·97(1)	—
65	17·43(3)	83·66(½)	—	61·42(6f)[3]	29·69(3f)	—
67	03·50(5)	—	—	46·43(3)	—	—
69	21488·61(2)	—	—	30·39(5)[2]	—	—

TABLE 5—Wave-Numbers of the Lines belonging to the (2, 17) Band.

K		R₁	R₂	R₃		P₁	P₂	P₃
17	...	—	—	21060·33(2)	...	—	—	21045·23(0)
19	...	—	21046·98(1)	57·85(1)	...	—	21029·94(3)	40·96(3)
21	...	—	44·29(3)	54·96(2)	...	—	25·16(1)	36·36(1f)
23	...	—	40·51(3)	51·69(2f)	...	—	20·18(4)?	31·30(1f)
25	...	—	36·50(4f)	47·89(3)	...	—	14·35(2)	25·77(1)
27	...	—	32·10(2)	43·73(2)	...	—	08·16(2)	19·87(½)
29	...	—	27·35(3)	39·10(3)	...	—	01·66(4)	13·56(4)
31	...	21045·05(2)	22·26(2)	34·08(3)	...	21017·75(1)	20994·79(4)	06·79(2)
33	...	39·33(3)	16·78(4)	28·62(3)	...	10·16(2)	87·56(3)	20999·60(2)
35	...	33·27(6)	10·84(5)	22·71(2)	...	02·32(2)	79·92(2)	91·97(1)
37	...	26·88(5)	04·49(4)	16·30(3)	...	20994·15(7)?	71·84(6f)?	83·90(2)
39	...	20·18(4)?	20997·74(10)?	09·42(2)	...	85·67(5)?	63·44(2)	75·36(3)
41	...	13·05(4)	90·56(4)	02·04(3)	...	76·82(2)	54·54(3)	66·32(5f)?
43	...	05·59(3)	82·94(3)	20994·15(7)?	...	67·58(3)	45·26(3f)?	56·86(2)
45	...	20997·74(10)?	74·84(2)	85·67(5)?	...	58·01(3)	35·48(3)	46·82(2)
47	...	89·47(3)	66·32(5f)?	76·61(1)	...	48·03(3)	25·29(2)	36·22(1)
49	...	80·82(2f)	57·20(2)	66·85(2)	...	37·69(4)	14·59(2)	25·02(2)
51	...	71·84(6f)?	47·56(4)	56·38(1)	...	26·97(3)	03·38(2)	13·16(1)
53	...	62·33(2)	37·34(2)	45·26(3f)?	...	15·78(4)	20891·65(3)	00·54(1)
55	...	52·45(3f)	26·54(2f)	—	...	04·23(3)	79·33(3)	20887·14(½)
57	...	42·13(2)	14·95(1)	—	...	20892·24(3)	66·37(½)	73·12(1)
59	...	31·32(2)	02·69(1)	—	...	79·83(3)	52·76(½f)	—
61	...	19·94(2f)	20889·60(½)	—	...	66·90(2)	38·39(2)	—
63	...	07·93(1)	75·64(1)	—	...	53·40(5)?	23·14(0)	—
65	...	20895·48(1)	—	—	...	39·51(1)	—	—
67	...	82·20(2)	—	—	...	24·62(0)	—	—
69	...	68·30(1f)	—	—	...	—	—	—

TABLE 6—Wave-Numbers of the Lines belonging to the (3, 17) Band.

K	R_1	R_2	R_3	P_1	P_2	P_3
3	21497·71(0)	—	21491·19(2)[3]	21493·93(0)	—	21488·89(3f)
5	21497·51(½)	21491·19(2)[3]	21491·19(2)[3]	21492·15(2f)	—	87·11(2)[3]
7	96·88(1)	90·53(1)	90·86(2)	89·78(3)	—	85·01(1f)
9	95·85(2)	89·51(1)	90·18(4f)[3]	87·11(2)[3]	21481·38(2)	82·48(2f)[3]
11	94·36(2)	88·07(1)	88·89(3f)	83·96(2)[2]	78·26(2f)	79·51(2)
13	92·52(2)	86·20(2)	87·11(2)[3]	80·47(2)	74·66(0f)	75·96(1)
15	90·18(4f)[3]	83·96(2)[2]	85·04(1f)	76·52(2)	70·65(2)[2]	72·21(6)[3]
17	87·57(2)	81·23(3)	82·48(2f)[2]	72·21(6)[3]	66·28(4)[2]	67·90(6)[2]
19	84·49(2)	78·10(1f)	79·51(2)[2]	67·39(2)	61·47(6f)[2]	63·13(1)
21	80·96(3)	74·58(1f)	76·10(4)	62·21(3)	56·25(4f)	57·96(2)
23	76·99(1)	70·65(2)[2]	72·21(6)[3]	56·60(3)	50·56(4)	52·41(3)
25	72·65(2)	66·28(4)[2]	67·99(2)	50·56(4)[2]	44·47(2)	46·41(3)
27	67·90(6)[2]	61·55(6f)[2]	63·34(2)	44·11(3)	37·96(2)	40·03(3)[2]
29	62·72(4)	56·44(3)	58·23(3)	37·23(2)	31·14(2)	33·16(3)
31	57·08(4)	50·95(5f)	52·62(2)	29·92(3)	23·88(2)	25·90(4)
33	51·08(5f)	45·02(4f)	46·57(3f)	22·19(2)	16·24(1)	18·16(3f)
35	44·58(2)	38·74(1)	40·03(3)[2]	14·05(2)	08·27(2f)[2]	09·95(3)
37	37·69(2)	32·07(2)	33·02(3)	05·48(4)	21399·84(1f)	01·27(3)
39	30·37(5)	25·00(3)	25·41(4)	21396·47(4)[3]	90·99(2)	21392·11(2)
41	22·60(2)	17·56(2)	17·14(1f)	87·06(4)	81·80(2)	82·32(3)
43	14·38(3)	09·71(3)	08·27(2f)	77·17(3)	72·16(4f)	72·02(2f)
45	05·68(2f)	01·46(2)	21398·73(2)	66·82(3f)	62·30(2)	61·00(3f)
47	21396·47(4)[3]	21392·81(3)	88·27(1)	55·98(3)	51·94(3)	49·25(1)
49	86·72(2)	83·65(4)	77·06(½)	44·69(2)	41·15(2)	36·71(½)
51	76·38(2)	74·05(2)	65·18(1)	32·85(3)	29·89(2)	23·46(2)
53	65·44(1)	63·95(2)	—	20·41(3)	18·02(2)	09·53(0f)
55	53·78(2)	53·55(2)		07·34(1)	05·82(2)	—
57	41·37(0)	42·77(1)	—	21293·59(1)	—	—
59	28·12(½)	—	—	79·07(½)	—	—
61	13·93(0)	—	—	63·69(2)	—	—
	—	—	—	47·41(1)	—	—

TABLE 7—Wave-Numbers of the Lines belonging to the (3, 18) Band.

K	R_1	R_2	R_3	P_1	P_2	P_3
5	20874·36(½)	20867·74(½f)[2]	20868·27(1f)	20868·95(0)	20863·00(1)[2]	20863·99(2f)[3]
7	73·74(½)	67·11(½)	67·74(½f)[2]	66·74(1)	60·80(2f)[2]	61·88(3f)[3]
9	72·77(1f)	66·17(½)	66·92(1)[2]	63·99(2f)[3]	58·09(1)	59·22(0)
11	71·37(1)	64·84(3)[2]	—	60·99(½)	55·03(½)	56·26(0)
13	69·58(2)	63·00(1)[2]	63·99(2f)[3]	57·58(1)	51·53(½f)	52·88(½f)
15	67·46(4)	60·80(2f)[2]	61·88(3f)[3]	53·72(3)	47·63(1)	49·10(1f)
17	64·84(3)[2]	58·22(1)	59·49(½)	49·49(2)	43·31(½)	44·85(5)[2]
19	61·88(3f)[1]	55·25(1)	56·64(2)	44·85(5)[2]	38·57(1)	10·33(2)
21	58·49(1)	51·82(1)	53·42(5)	39·76(3)	33·48(1)	35·30(1)
23	54·69(2)	48·06(2)	49·70(2)	34·34(5d)[2]	28·00(1)	29·87(½f)
25	50·50(3)	43·88(1)	45·63(2)	28·42(2)	22·08(6)[2]	24·01(2)
27	45·90(2)	39·34(2)	41·12(3)	22·08(6)[2]	15·78(2)	17·80(4)
29	40·89(3)	34·34(5d)[2]	36·19(3)	15·42(2)	09·10(2)	11·15(1)
31	35·45(3)	29·08(2)	30·81(3)	08·31(3)	02·04(3)	04·07(7)[2]
33	29·65(2)	23·39(5)[2]	24·98(2)	00·80(2)	20794·61(2)	20796·55(4)[2]
35	23·39(5)[2]	17·33(3)	18·69(2)	20792·87(3)	86·79(2)	88·57(3)
37	16·74(4)	10·89(4)	11·88(3)	84·52(3)	78·62(3)[2]	80·15(1)
39	09·68(3)	04·07(7)[2]	04·53(1)	75·75(2)	70·06(2)	71·20(1)
41	02·15(3)	20796·90(2)	20796·55(4)[2]	66·60(2)	61·13(2)	61·72(1)
43	20794·21(1)	89·33(2)	87·92(1f)	56·97(2)	51·82(2)	51·66(2)
45	85·77(1)	81·39(3)	78·62(3)[2]	46·92(3f)	42·15(2)	40·93(1)
47	76·87(2)	73·03(3)	68·55(½)	36·38(2)	32·10(1)	29·47(½)
49	67·44(1)	64·20(2)	—	25·37(1)	21·63(1)	17·27(½)
51	57·42(2)	54·77(3)	—	13·85(1f)	10·67(1f)	—
53	46·80(1)	—	—	01·73(1)		
55	35·47(2f)	—	—	20689·02(1)		—
57	23·46(0)	—	—	—	—	—

TABLE 8—Wave-Numbers of the Lines belonging to the (3, 19) Band.

K	R_1	R_2	R_3	P_1	P_2	P_3
5	20257·10(0)	—	—	20251·67(0)	—	—
7	56·38(0)	20249·19(1d)	—	49·26(1)	—	—
9	55·47(½)	48·56(1)	—	46·72(1)	20240·40(2)[1]	—
11	54·18(1)	47·25(1)	20247·90(3f)	43·76(1)	37·48(½)	—
13	52·45(1)	45·57(½)	46·48(0)	40·40(2)[2]	34·05(2)[2]	20235·37(0)
15	50·37(1)	43·51(1)	44·59(1)	36·68(1)	30·26(1)	31·71(½)
17	47·90(3)	40·99(1)	42·24(1)	32·48(1)	26·06(1)	27·63(2)
19	45·02(2)	38·11(3)[1]	39·53(1)	27·94(2)	21·45(1)	23·17(3)
21	41·75(2)	34·83(1)	36·34(2)	23·03(3)	16·46(1f)	18·26(1)
23	38·11(3)[2]	31·19(1)	32·88(1)	17·69(1)	11·08(1f)	13·06(4)[2]
25	34·05(2)[2]	27·16(2)	28·92(3)	11·95(2)	05·33(1)	07·32(4)[2]
27	29·61(2)	22·80(2)	24·62(2)	05·83(2)	20199·25(5)[2]	01·25(2)
29	24·78(3)	18·05(2)	19·87(2)	20199·25(5)[2]	92·71(1)	20194·83(3f)
31	19·55(2)	12·96(4)[2]	14·66(2f)	92·37(3)	85·87(2)	87·89(1)
33	13·94(2)	07·40(4)[2]	09·05(2)	85·07(3)	78·63(4)	80·60(3f)
35	07·92(3)	01·56(4f)[2]	02·99(2)	77·37(2)	71·05(3)	72·86(2)
37	01·46(4f)[2]	20195·39(3)	20196·41(2)	69·26(1)	63·13(3)	64·69(2)
39	20194·65(3f)[2]	88·52(3f)	89·31(3)	60·74(2)	54·80(2)	56·00(2)
41	87·40(2)	81·91(3)	81·65(2)	51·83(2)	46·12(2)	46·75(1)
43	79·72(3f)	74·63(2)	73·29(2)	42·49(2)	37·09(3f)	36·98(2f)
45	71·55(2)	66·97(3)	64·26(1)	32·72(1f)	27·72(3)	26·58(1)
47	62·98(2)	58·89(2)	54·46(0)	22·49(3)	17·97(2)	15·39(½)
49	53·86(1)	50·38(3)	43·81(0)	11·77(2)	07·80(1)	03·50(0)
51	44·17(1)	41·25(1)	—	00·59(1)	20097·23(1)	—
53	33·81(1f)	—	—	20088·78(2)	86·02(2)	—
55	22·93(½)	—	—	76·46(1)	—	—
57	11·20(½)	—	—	63·43(0)	—	—
59	20098·72(0)	—	—	49·69(½)	—	—

TABLE 9—The Values of $\Delta_2F'_1(K)$ for the $v'=1$, 2 and 3 Vibrational Levels.

	$\Delta_2F'_1(K)=F'_1(K+1)-F'_1(K-1)=R_1(K)-P_1(K)$									
	$v'=1$.			$v'=2$.			$v'=3$			
K	(1, 14)	(1, 15)	Olsson.	(2, 16)	(2, 17)	Olsson.	(3, 17)	(3, 18)	(3, 19)	Olsson.
1	2.20	—	—	—	—	—	—	—	—	—
3	3·77	—	—	—	—	—	3·78	—	—	—
5	5·44	—	—	—	—	—	5·38	5·41	5·43	—
7	7·09	—	—	—	—	—	7·10	7·00	7·12	—
9	8·81	8·73	—	—	—	—	8·74	8·78	8·75	—
11	10·44	10·40	—	—	—	—	10·40	10·38	10·42	—
13	12·10	12·13	—	—	—	—	12·05	12·00	12·05	—
15	13·86	13·87	—	—	—	—	13·66	13·74	13·69	13·76
17	15·59	15·59	15·58	—	—	—	15·36	15·35	15·42	15·24
19	17·32	17·26	17·30	—	—	—	17·10	17·03	17·08	17·02
21	18·99	18·96	18·98	—	—	—	18·75	18·73	18·72	18·72
23	20·72	20·61	20·69	—	—	—	20·39	20·35	20·42	20·44
25	22·37	22·43	22·38	—	—	22·04	22·09	22·08	22·10	22·12
27	24·12	24·13	24·15	—	—	23·83	23·79	23·82	23·78	23·75
29	25·82	25·79	25·74	—	—	25·60	25·49	25·47	25·53	25·44
31	27·52	27·52	27·36	27·27	27·30	27·31	27·14	27·15	27·18	27·15
33	29·18	29·18	29·15	29·19	29·17	29·21	28·89	28·85	28·87	28·88
35	30·86	30·79	30·67	30·92	30·95	30·89	30·53	30·52	30·55	30·61
37	32·45	32·49	32·53	32·77	32·73	32·75	32·21	32·22	32·20	32·18
39	34·11	34·05	34·16	34·52	34·51	34·45	33·90	33·93	33·91	33·87
41	35·76	35·74	35·72	36·21	36·23	36·27	35·55	35·54	35·57	35·67
43	37·30	37·29	37·30	37·90	38·01	37·99	37·21	37·24	37·23	—
45	38·84	38·86	38·86	39·70	39·73	39·75	38·86	38·85	38·83	
47	40·36	40·36	40·40	41·48	41·44	41·41	40·49	40·49	40·49	—
49	41·85	41·86	—	43·12	43·13	43·14	42·03	42·07	42·09	—
51	43·29	43·29	—	44·84	44·87	44·81	43·53	43·57	43·58	
53	44·83	44·80	—	46·53	46·55		45·03	45·07	45·03	—
55	—	46·36	—	48·20	48·22	—	46·44	46·45	46·47	—
57	—	—	—	49·85	49·89	—	47·78		47·77	—
59	—	—	—	51·49	51·49	—	49·05		19·03	—
61	—	—	—	53·07	53·04	—	—	—	—	—
63	—	—	—	54·51	54·53	—	—	—	—	—
65	—	—	—	55·96	55·97	—	—	—	—	—
67	—	—	—	—	57·58	—	—	—	—	—

TABLE 10—The Values of $\Delta_2 F'_2(K)$ for the $v'=1$, 2 and 3 Vibrational Levels.

$\Delta_2 F'_2(K) = F'_2(K+1) - F'_2(K-1) = R_2(K) - P_2(K)$

K	$v'=1$. (1, 14)	(1, 15)	Olsson.	$v'=2$. (2, 16)	(2, 17)	Olsson.	$v'=3$. (3, 17)	(3, 18)	(3, 19)	Olsson.
5	4·87	—	—	—	—	—	—	4·74	—	—
7	6·60	—	—	—			—	6·31	—	—
9	8·43	8·41	—	—			8·13	8·08	8·16	—
11	10·17	10·14	—	—			9·81	9·81	9·77	—
13	11·91	12·01	—	—			11·54	11·47	11·52	—
15	13·67	13·70	—	—		—	13·21	13·17	13·25	13·25
17	15·46	15·41	15·44	—			14·94	14·91	14·93	14·97
19	17·27	17·18	17·22	—	—		16·63	16·68	16·66	16·77
21	18·98	18·97	18·96	—	—		18·33	18·34	18·37	18·38
23	20·79	20·84	20·76	20·43	20·33	20·29	20·09	20·06	20·11	20·05
25	22·47	22·48	22·47	22·16	22·15	22·15	21·81	21·80	21·81	21·80
27	21·27	24·21	24·30	23·95	23·94	23·93	23·59	23·56	23·58	23·54
29	26·03	25·97	26·01	25·66	25·69	25·69	25·30	25·24	25·34	25·31
31	27·80	27·77	27·81	27·43	27·47	27·36	27·07	27·04	27·09	27·08
33	29·52	29·50	29·53	29·22	29·22	29·28	28·78	28·78	28·77	28·81
35	31·26	31·21	31·22	30·92	30·92	30·89	30·47	30·54	30·51	30·54
37	32·94	32·95	32·94	32·67	32·65	32·68	32·23	32·27	32·26	32·29
39	34·51	34·52	34·51	34·32	34·30	34·31	34·01	34·01	34·02	33·97
41	—	35·62	35·55	36·02	36·02	36·05	35·76	35·77	35·79	35·75
43	—	37·42	37·43	37·67	37·68	37·76	37·55	37·51	37·54	—
45		—	—	39·35	39·36	39·37	39·16	39·24	39·25	
47		—	—	41·01	41·03	40·99	40·87	40·93	40·92	
49	—	—	—	42·59	42·61	42·59	42·50	42·57	42·58	—
51		—	—	44·23	44·18	44·14	44·16	44·10	44·02	—
53	—	—	—	45·68	45·69	45·50	—	—	—	—
55	—	—	—	47·25	47·21	—	—	—	—	—
57	—	—	—	48·59	48·58	—	—	—	—	—
59	—	—	—	50·02	—	—	—	—	—	—
61	—	—	—	51·38	—	—	—	—	—	—
63	—	—	—	52·56	—	—	—	—	—	—
65	—	—	—	53·97	—	—	—	—	—	—

TABLE 11—The Values of $\Delta_2 F'_3(K)$ for the $v'=1$, 2 and 3 Vibrational Levels.

$\Delta_2 F'_3(K) = F'_3(K+1) - F'_3(K-1) = R_3(K) - P_3(K)$.

K	$v'=1$. (1, 14)	(1, 15)	Olsson.	$v'=2$. (2, 16)	(2, 17)	Olsson.	$v'=3$. (3, 17)	(3, 18)	(3, 19)	Olsson
5	1·53	—	—	—	—		4·08	4·28	—	—
7	6·14	—	—	—			5·82	5·86	—	—
9	7·81	7·73	—	—			7·70	7·70	—	—
11	9·59	9·57	—	—			9·38	9·40	—	—
13	11·40	11·47	—	—	—		11·15	11·11	11·11	—
15	13·15	13·12	—	—	—		12·83	12·78	12·88	12·81
17	14·92	14·93	—	15·11	15·10		14·58	14·64	14·61	14·60
19	16·72	16·62	16·51	16·87	16 89		16·38	16·31	16 36	16·37
21	18·41	18·44	18·41	18·68	18 60	—	18·14	18·12	18·08	18·11
23	20 06	20·06	20 10	20·44	20 39	20·33	19·80	19 83	19·82	20·14
25	21·86	21·74	21·81	22·13	22 12	22·16	21·58	21·62	21·60	21·57
27	23·45	23·42	23·39	23·86	23 86	23·87	23 31	23·32	23·37	23·41
29	25 07	25·16	25·13	25·59	25 61	25·55	25 07	25·04	25·04	25·12
31	26·66	26·66	26·73	27·31	27·29	27·31	26·72	26·74	26·77	26·66
33	28·21	28·20	28·21	29·09	29 02	28 98	28·41	28·43	28·45	28·42
35	29·70	29·76	29·77	30·74	30·74	30·72	30·08	30·12	30·13	30·01
37	31·25	31·26	31·28	32·44	32·40	32·38	31·75	31·73	31·72	31·74
39	32·78	32·77	32·75	34·08	31 06	84·05	33·30	33·33	33·31	33·58
41	34·32	34·24	34·28	35·78	35·72	35·74	34 82	31·83	31·90	34·85
43	—	35·71	—	37·33	37 29	37·30	36 25	36 26	36·31	—
45	—	37·27	—	38·94	38·85	38·90	37 68	37·69	37·68	—
47	—	—	—	40·39	40·39	40 35	39 25	—	39·07	—
49		—	—	41·94	11 83	41 81			—	—
51		—	—	43·32	43 22	43·21				—
53	—	—	—	44·72	14·72	44·50		—	—	—
55	—	—	—	46·29	—	—		—	—	—

TABLE 12—The Values of $\Delta_2 F''_1(K)$ for the $v''=17$ Vibrational Level.

$\Delta_2 F''_i(K) = F''_i(K+1) - F''_i(K-1) = R_i(K-1) - P_i(K+1)$

K		$\Delta_2 F''_1(K)$ (2, 17)	$\Delta_2 F''_1(K)$ (3, 17)		$\Delta_2 F''_2(K)$ (2, 17)	$\Delta_2 F''_2(K)$ (3, 17)		$\Delta_2 F''_3(K)$ (2, 17)	$\Delta_2 F''_3(K)$ (3, 17)
		$v''=17$							
4	...	—	5·58	...	—	—	...	—	4·08
6	...	—	7·73	...	—	—	...	—	6·18
8	...	—	9·77	...	—	9·15	...	—	8·30
10	...	—	11·89	...	—	11·25	...	—	10·67
12	...	—	13·89	...	—	13·41	...	—	12·93
14	...	—	16·00	...	—	15·55	...	—	14·90
16	..	—	17·97	...	17·73	17·68	...	—	17·14
18	...	—	20·18	...	19·83	19·76	...	19·37	19·35
20	.	—	22·28	...	21·82	21·85	...	21·49	21·55
22	...	—	24·36	...	24·11	24·02	...	23·66	23·69
24	...	—	26·43	...	26·16	26·18	...	25·92	25·80
26	...	—	28·54	...	28·34	28·32	...	28·02	27·96
28	...	30·63	30·67	...	30·44	30·41	...	30·17	30·18
30	...	32·78	32·80	...	32·56	32·56	...	32·31	32·33
32	...	34·89	34·89	...	34·70	34·71	...	34·48	34·44
34	...	37·01	37·03	...	36·76	36·75	...	36·65	36·62
36	...	39·12	39·10	.	39·00	38·90	...	38·81	38·75
38	...	41·21	41·22	...	41·05	41·08	...	40·94	40·91
40	...	43·36	43·31	...	43·20	43·20	...	43·10	43·09
42	...	45·47	45·43	...	45·30	45·40	...	45·18	45·12
44	...	47·58	47·56	...	47·46	47·42	...	47·33	47·22
46	...	49·71	49·70	...	49·55	49·52	...	49·45	49·48
48	...	51·78	51·78	...	51·73	51·66	...	—	51·79
50	...	53·85	53·87	.	53·84	53·76	...	—	54·01
52	...	56·06	55·97	...	55·91	56·03	...	—	56·17
54	...	58·10	58·10	...	58·01	58·13	...	—	—
56	...	60·21	60·19	...	60·17	—	...	—	—
58	...	62·30	62·30	...	62·19	—	...	—	—
60	...	64·42	64·43	...	64·30	—	...	—	—
62	...	66·54	66·52	...	—	—	...	—	—
64	...	68·42	—	...	—	—	...	—	—
66	...	70·66	—	...	—	—	...	—	—

TABLE 13—The Molecular Constants

v''	B''_v			B''_e, r''_e, α''_e and D''_e
27	0·2503	±·0001	(Naudé)	——
25	0·2539	,,	,,	——
24	0·2556	,,	,,	——
23	0·2568	,,	,,	——
22	0 2589	,,	,,	——
19	0·2633	,,	,,	——
18	0·2651	,,	,,	——
17	0·2666	±·0002	,,	B''_0 (extrapolated) =0·2947 cm^{-1}
16	0·2681	±·0001	,,	——
15	0·2700	,,	,,	B''_e=0 2956 cm^{-1}
14	0·2716	,,	,,	——
8	0·2819	±·0002	(Wilson)	r''_e=1 893 x 10^{-8} cm
7	0·2834	,,	,,	——
4	0 2883		(Olsson)	α''_e=0 0016 cm^{-1}
3	0 2896	,,	,,	——
2	0·2915	± 0001	,,	D''_e= – 19·6 x 10^{-8} cm^{-1}

v'	B'_v			B'_e, r'_e α'_e and D'_e
7	0·2085	±·0002	(Naudé)	——
6	0·2102	±·0001	,,	——
5	0·2102	,,	,,	——
4	0·2150	,,	,,	B'_e=0·2219 cm^{-1}
3	0·2129	,,	,,	——
3	0·2136	(Olsson replotted)		r'_e=2·184 x 10^{-8} cm
2	0·2175	±·0001	(Naudé)	——
2	0·2177	(Olsson replotted)	...	α'_e=0·0018 cm^{-1}
1	0·2205	±·0001	(Naudé)	——
1	0·2200	(Olsson replotted)	...	D'_e= – 23·1 x 10$^{-?}$ cm^{-1}
0	0·221	±·001	(Wilson)	——

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TRACE ELEMENTS IN CLAYS

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Introductory.

While carrying out investigations on various clays, particularly those of South Africa, it was felt that a knowledge of the minor elements associated with the clay minerals would be of value. A large quartz spectrograph being available, it was decided to attempt the determinations spectrochemically, since that method usually affords rapid and sensitive tests for most metals and certain non-metals. Spectrochemical analysis has already been used for the analysis of trace elements in clays and a description of the spectrochemical procedure used and the results obtained in the analysis of four American clays, has recently appeared in the literature (Austin and Bassett, 1941).

Experimental.

Although spectrochemists frequently employ " Cathode Layer " excitation for the analysis of rocks, minerals, soils, etc., Pierce, Torres and Marshall (1940), have found that for the materials they have analysed, provided a sufficient quantity is available, anode excitation is more convenient and at the same time equally sensitive. " Cathode Layer " technique has as yet, not been attempted in this laboratory, so that comparisons cannot be made, but experience has shown, and this is important, that provided a judicious choice of electrode shapes and operating conditions is made, ordinary anode excitation provides a very satisfactory sensitivity.

The operating conditions which were found to provide the most satisfactory results, particularly for very volatile and very involatile elements, are described briefly below.

A carbon anode of 5mm. diameter containing a bore of 4·5mm. depth and 3·0mm. diameter, was used to hold the material, the cathode, also of carbon, being sharpened to a point. After exposing for twenty seconds the radiations emitted from an arc run at 2½ amps, the current was increased to 6½ amps (the highest available) and successive exposures of twenty seconds were made until the material had volatilised completely. Preliminary arcing at 2½ amps was found beneficial for volatile

elements such as Pb, Sn, Ga, Ag, Cd, Zn, etc. Complete volatilisation was essential, since unless this was ensured, certain of the very involatile elements such as Zr, failed to record their spectra, even when present in considerable quantities. An arc gap of 5 mm. was maintained throughout, the line voltage being 250 volts.

Difficulty was quite often encountered as a result of the ejection of material out of the anode when the arc was struck, the resultant spectrogram being useless for analysis. This phenomenon was usually exhibited by extremely fine particled clays. This difficulty was usually overcome by loading the anode in the usual manner and then scooping out some of the material so as to form a v-shaped depression in the centre. When not looking for the alkalis, the addition of a small amount of alkali chloride often aids in preventing an excessive loss of material.

In order to detect Tl, each analysis had to be repeated. The line used, Tl 3775.72, is located in a cyanogen band, and unless Tl is present in quantity, the line is completely masked. The development of cyanogen emitters is prevented by adding 5 to 10 per cent. KCl to the material under observation. Since the ionisation potential of K is low (4·32 volts) there is a lowering of the arc temperature and hence the presence of K vapour depresses the volatilisation of most elements, particularly those whose compounds (in the case of clays, rocks, etc., usually the oxides) have very high boiling points, and whose lines possess high excitation potentials. Tl is volatile, however, and since Tl 3775 has a low excitation potential (3·3 volts), the presence of K provides conditions ideal for its emission.

Subsequent work on the quantitative analysis of Tl in rocks, soils and clays, showed that Tl may be detected in concentrations as low as about 0·00003 per cent. This is a surprising sensitivity, as van Tongeren (1938) using Tl 3775 and "Cathode Layer" excitation reported a sensitivity of 0·01 per cent., while Mitchell (1940) who also used "Cathode Layer" excitation, but employed Tl 2767·87, reported a sensitivity of 0·005 per cent Tl.

The wavelength range examined being between 5,000 and 2,810 A, (corresponding to a single setting of the spectrograph) B, P, Au, and Te were excluded from analysis as none of their sensitive lines lie in this range. The common elements always found in clays, Ca, Mg, Ti, Fe, as well as Al and Si were omitted from analysis, and since the spectrograph possessed quartz and not glass optics, a systematic search for the rare earth elements was neglected, although two typical members, Yt and La, were determined.

Results of the Analyses.

In all, thirty-four clays from various localities were analysed for the following elements, Ag, Ba, Be, Bi, Cb, Cd, Co, Cr, Cu,

Ga, Ge, In, K, La, Li, Mn, Mo, Na, Ni, Pb, Pd, Pt, Sb, Sc, Sn, Sr, Tl, V, W, Yt, Zn and Zr.

Table 1 provides the results of the analyses. For convenience, each clay sample has been given a number, but a short description of each sample is given in Table 2. In the first part of Table 1 (samples 1 to 8), the second column gives the amount in the earth's crust for each element analysed, in grams per ton, as stated by Goldschmidt (1937). In the following columns a figure (1, 2 or 3) denotes that a particular element was definitely detected in the sample analysed and also provides a rough indication of the relative amount present; 3 indicating a strong line, 2 a line of medium intensity and 1 a faint but definite line.

TABLE I.

	Amount of elements in earth's crust (gms. per ton).	1	2	3	4	5	6	7	8
Ag	0·1	—	—	1	1?	1	—	1?	1
Ba	390	2	2	1	1	1	1	1	1
Be	6	—	—	—	—	—	—	—	—
Bi	0·2	—	—	—	—	—	—	—	—
Cb	15	—	—	—	—	—	—	—	—
Cd	0·5	—	—	—	—	—	—	—	—
Co	40	1	1	1	1?	1	1	1	2
Cr	200	2	2	3	3	1	3	2	2
Cu	100	1	1	1	1	1	1?	2	1
Eu	1·0	—	—	—	—	—	—	—	—
Ga	15	2	2	2	2	3	2	2	2
Ge	7	—	—	—	—	—	—	—	—
In	0·1	—	—	—	—	—	—	—	—
K	25,900	3	—	—	1	1	1	1?	1
La	19	—	—	—	—	—	—	—	—
Li	65	—	—	—	—	—	—	—	—
Mn	930	2	1	2	2	2	3	2	2
Mo	15	1	—	—	—	—	—	—	—
Na	28,300	2	—	1?	2	1	—	2	2
Ni	100	1	2	2	2	1?	1?	2	2
Pb	16	1	—	2	1	1	—	1	2
Pd	0·01	—	—	1	—	—	—	1?	—
Pt	0·005	—	—	—	—	—	—	—	—
Sb	1?	—	—	—	—	—	—	—	—
Sc	5	—	1	—	1?	2	1	—	—
Sn	40	—	—	2	1?	—	—	1	1
Sr	420	2	1	1	2	1	—	1?	1?
Tl	0·3	1?	—	1	1	1?	1?	1	1
V	100	2	2	3	2	1	3	2	2
Yt	31	1	1	—	1	—	—	—	—
Zn	40	—	—	—	—	—	—	—	—
Zr	190	1	2	1	1	—	1	1	1

	9	10	11	12	13	14	15	16	17
Ag	1	—	1	1?	1	1	—	—	—
Ba	2	—	1	2	3	2	2	2	2
Be	—	—	—	—	—	—	—	—	—
Bi	—	—	—	—	—	—	—	—	—
Cb	—	—	—	—	—	—	—	—	—
Cd	—	—	—	—	—	—	—	—	—
Co	1	1?	1	2	1	1	1	2	2
Cr	2	2	2	2	1	2	2	2	2
Cu	2	1	1	2	2	2	1	2	1?
Eu	—	—	—	—	—	—	—	—	—
Ga	1	1	2	1	1	1	2	2	2
Ge	—	—	—	—	—	—	—	—	—
In	—	—	—	—	—	—	—	—	—
K	1	—	1?	2	2	1	2	2	3
La	—	—	—	—	—	—	—	—	—
Li	1	—	—	2	1	1?	1	1	1
Mn	2	2	1	3	3	2	1	2	3
Mo	—	—	—	—	—	1?	—	—	—
Na	2	—	1	3	3	3	2	3	3
Ni	2	1	2	2	1	2	1	2	1
Pb	1	—	—	1?	1	1?	1	—	1
Pd	—	—	—	—	—	—	—	—	—
Pt	—	—	—	—	—	—	—	—	—
Sb	—	—	—	—	—	—	—	—	—
Sc	1	2	2	—	—	1	1	1	—
Sn	—	—	—	—	1	—	—	1	—
Sr	2	2	1?	2	3	2	2	2	3
Tl	1	—	1	—	—	—	—	1?	1
V	2	2	2	2	1	2	2	2	2
Yt	1?	1	1	1	1?	1	1	1	1
Zn	—	—	—	—	—	—	—	1?	—
Zr	1	2	2	2	1	2	1	1	1

	18	19	20	21	22	23	24	25	26
Ag	—	1?	—	—	1	2	—	—	—
Ba	2	3	2	2	1	3	2	1	1
Be	—	—	—	—	—	—	—	—	—
Bi	—	—	—	—	—	—	—	—	—
Cb	—	—	—	—	—	—	—	—	—
Cd	—	—	—	—	—	—	—	—	—
Co	2	2	2	2	2	1?	1	1	2
Cr	2	2	2	3	1?	1?	3	3	2
Cu	1?	1	1	2	1	1	1	2	1
Eu	—	—	—	—	—	—	—	—	—
Ga	2	2	1	1?	3	—	2	1	1
Ge	—	—	—	—	—	—	—	—	—
In	—	—	—	—	—	—	—	—	—
K	2	2	—	—	2	—	1	—	—
La	—	—	—	—	—	—	—	—	—
Li	1	1	—	—	—	—	1	—	—
Mn	3	2	2	3	2	1	2	1	1
Mo	—	—	1?	—	—	—	—	2	—
Na	3	2	2	—	2	1?	2	1	—
Ni	1	2	1	2	1	1	2	2	2

	18	19	20	21	22	23	24	25	26
Pb	1	1	—	—	2	1	1?	—	—
Pd	—	—	—	—	—	—	—	—	—
Pt	—	—	—	—	—	—	—	—	—
Sb	—	—	—	—	—	—	—	—	—
Sc	—	1	—	2	—	—	1	1	2
Sn	—	—	—	—	1	3	—	1	1
Sr	3	2	2	1	—	2	2	2	1
Tl	1	1	1	—	2	—	1?	—	—
V	2	2	2	2	—	—	2	3	2
Yt	1	2	1	1	—	—	—	—	2
Zn	—	—	1?	1	—	1	—	—	—
Zr	1	2	3	2	—	—	2	2	3

		27	28	29	30	31	32	33	34
Ag	...	—	—	1?	—	—	—	2	—
Ba	...	2	2	1?	3	—	3	2	2
Be	...	—	—	—	—	—	—	—	—
Cb	...	—	—	—	—	—	—	—	—
Bi	...	—	—	—	—	—	—	—	—
Cd	...	—	—	—	—	—	—	—	—
Co	..	—	1	2	1	1?	—	2	2
Cr	..	3	2	3	2	2	3	1	3
Cu	...	—	1	2	1?	2	2	3	3
Eu	...	—	—	—	—	—	—	—	—
Ga	...	2	2	1	1	1	3	2	3
Ge	...	—	—	—	—	—	—	—	—
In	...	—	—	—	—	—	—	—	—
K	...	2	3	1	2	—	3	2	3
La	...	—	—	—	—	—	—	—	—
Li	...	1?	2	1	1	1	1	—	1
Mn	...	1	3	—	3	2	1	3	3
Mo	...	—	—	—	—	—	—	—	1
Na	...	2	3	1	3	1	3	1	3
Ni	...	1	1	3	1	1	3	2	3
Pb	...	1	1?	1	1	—	1	2	1
Pd	...	—	—	—	—	—	—	—	—
Pt	...	—	—	—	—	—	—	—	—
Sb	...	—	—	—	—	—	—	—	—
Sc	...	1?	—	1	1	—	2	—	—
Sn	...	—	1	1	—	—	1	—	1
Sr	...	2	2	2	3	—	3	1	2
Tl	...	1	1?	1?	1?	—	0·00029%	0·0007%	1?
V	...	2	1	2	2	2	3	1?	3
Yt	...	1	2	1?	1	—	1	—	—
Zn	...	—	—	—	—	—	—	1	—
Zr	...	3	3	2	2	—	2	—	—

The following figures give the number of different samples in which each element was definitely detected—Ag 10 (i.e., in 10 different samples), Ba 30. Cd 1, Co 28, Cr 32, Cu 29, Ga 32, K 23, Li 15, Mn 33, Mo 2, Na 28, Ni 32, Pb 20, Pd 1, Sc 17, Sn 13, Sr 28, Tl 14, V 31, Yt 18, Zn 3, Zr 28.

The elements Be, Cb, Bi, Eu, Ge, In, La, Pt and Sb were not definitely found in any sample.

TABLE II.

Sample No.	Locality.	Description.
1.	U.S.A.	U.S. Bur. Stds., Sample No. 98.
2.	Lawley, Transvaal, South Africa.	Fine grained plastic clay.
3.	Boksburg, Transvaal, South Africa.	Haematitic flint clay.
4.	Kaalfontein, Transvaal, South Africa.	Blue kaolinitic fire clay.
5.	Arnot, Transvaal, South Africa.	White residual clay.
6.	Ndwedwe, Natal, South Africa.	Kaolin.
7.	Potchefstroom, Transvaal, South Africa.	Recent montmorillonite clay.
8.	Vereeniging, Transvaal, South Africa.	Kaolinitic fire clay.
9.	Prov. Allemagne, Belgium	Kaolinitic clay.
10.	Prov. Francaise, Belgium	Kaolinitic clay.
11.	Prov. Belgique, Belgium .	Kaolinitic clay.
12.	El Alamein, Egypt ...	Marine clay, rich in Fe minerals.
13.	Gilbana, Sinai	Saline lacustrine clay.
14.	Above Qattara Depression, Egypt.	Highly saline marine clay.
15.	Riversdale, Cape Province, South Africa.	Kaolinitic montmorillonite clay.
16.	Qattara Depression, Egypt	Highly saline marine clay.
17.	Port Elizabeth, Cape Province, South Africa.	Kaolinitic illite clay.
18.	Port Elizabeth, Cape Province, South Africa.	Kaolinitic illite clay.
19.	Grahamstown, Cape Province, South Africa.	Clay from weathered shales.
20.	East London, Cape Province, South Africa.	Clay from weathered shales.
21.	Lichtenberg, Transvaal, South Africa.	——
22.	Mozambique	Kaolin.
23.	England	Nontronite.
24.	Glenboig, Ayrshire, Scotland.	Bauxitic kaolinite.
25.	Glenboig, Ayrshire, Scotland.	Kaolinite.
26.	Akron, Ohio, U.S.A. ...	Kaolinitic clay.
27.	Golden, Colorado, U.S.A. .	Kaolinitic clay.
28.	Wyoming, U.S.A. ...	Montmorillonite.
29.	Missouri, U.S.A. ...	Kaolinitic clay.
30.	Harlingen, Holland ...	Fine grained loess.
31.	Alicedale, Cape Province, South Africa.	Pure kaolin.
32.	Port Nolloth, Cape Province, South Africa.	Pyrophillite-hydromica series.
33.	Georgia, U.S.A.	Ferruginous clay.
34.	Vermillion, South Dakota, U.S.A.	Pure illite.

Discussion of the Results.

Trace elements associated with the various clay minerals may be regarded as existing.

(a) in the form of discrete mineral fragments,

(b) in solid solution, replacing Al and Si, or even Fe, Mg, and Ca, depending on the clay mineral concerned,

(c) in some type of double layer surrounding the clay colloid and capable of cation exchange, and

(d) as loosely held ions between the structural layers of the clay mineral, the open structure of which permits considerable freedom of movement of impurity ions. These ions are also capable of cation exchange, and it is difficult to differentiate between conditions (c) and (d).

The frequent occurrence of the common elements, Ti and Fe, as well as Cr, V, Mn, Co, Ni, etc., is not surprising, since most clay minerals are contaminated by a considerable quantity of discrete mineral particles, most of which contain the commoner elements in some quantity. Some may, however, exist in solid solution, and it would be of interest to investigate ionic radius and its influence on solid solution in clay minerals, bearing in mind the open structures of the clay mineral lattices. Some elements again, are capable of cation exchange and even rare elements such as Ce have been found capable of exchange. It would be useful to investigate systematically the influence of ionic potential $\left(\frac{\text{valence}}{\text{radius}}\right)$ on the ease of adsorption of cations in the clay colloid. In the case of zeolites, for example, those cations which possess larger ionic potentials than 2·0 are not adsorbed.

Although some rare elements are sometimes present in clays, their distribution appears to be somewhat haphazard. However, Tl, Ga and Sc, all three rare elements, were found to be frequently associated with the clay minerals, and their distribution will be discussed in some detail.

Thallium.

Tl is of unusual interest, since its role as an element is characteristically that of a "Dr. Jekyll and Mr. Hyde." While resembling Ag, Cu, and Pb, on the one hand, and occurring with these elements in some obscure rare sulphides, this Group 3 element has many properties which show close analogy with those of the alkalis, particularly K and Rb. Of practical geochemical interest is the similarity between their ionic radii, those of Rb^+ and Tl^+ being 1·49 A, while that of K^+ is 1·33 A, with the result that Tl is invariably found together with Rb in K rich minerals. (The average Tl contents of five South African potash feldspars that have been analysed spectro-

chemically, is 0·0004 per cent. Tl.) During the process of weathering, Tl is led away in true ionic solution, and probably during the percolation of clay-like materials, it is partly adsorbed in the same way as the alkalis. Goldschmidt (1933) has shown that the clay sediments adsorb the alkalis preferentially, Rb and Cs being particularly strongly adsorbed. The same may be said of the rare alkaline earth ions, Ba being very strongly adsorbed. Since Tl shows such close analogy to Rb, their ionic potentials being identical (0·67), it is to be expected that Tl should be readily adsorbed by the clay colloid.

In the samples so far analysed, Tl appears to be present usually when appreciable amounts of the alkalis are also present, although in the case of certain highly saline clays from Egypt (Nos. 12, 13, 14 and 16), Tl could not be detected.

Two interesting observations may be noted here. A sample of Umgeni River water was found to contain 0·03 per cent. Tl of the total solid in solution, while an examination of sea water at Durban failed to reveal the presence of Tl, so that if present, it will be in quantities less than 0·00003 per cent. Tl of the solids in solution.

Clay No. 33, containing 0·0007 per cent. Tl, is the richest in Tl. However, since Ag, Cu and Pb lines are also unusually strong, it would appear that Tl is associated with these elements in some complex sulphides, as discrete mineral fragments, and is not adsorbed in the clay colloid itself.

Gallium.

The presence of Ga in nearly all the samples analysed is not surprising, since Ga shows, in many respects, close analogy to Al. Largely as a result of the similarity between their ionic radii (Al^{+++}=0·57 A, Ga^{+++}=0·62 A), Ga is invariably found in minerals rich in Al in the primary rocks. The process of weathering with the formation of clays is unlikely to destroy their relationship and it is probable that Ga^{+++} enters into the clay lattice replacing Al^{+++} in substitutional solid solution. It might be stated that Ga is an almost constant "impurity" in clays, since even the purest of clays contain this element. Goldschmidt (1931) has analysed a few clays spectrochemically for Ga, and his results indicate that the Ga content is usually between 0·01 and 0·001 per cent Ga_2O_3.

When the clay mineral is not particularly rich in Al it is possible that Ga may be absent. This was found to be the case with the rare hydrated iron silicate, nontronite. Only one sample was available for analysis, but fortunately it was very pure, and Ga definitely could not be detected.

Scandium.

Although once believed to be a very rare element, Sc is extremely widely distributed throughout the lithosphere in very

small quantities and has been detected in nearly all rocks, where it occurs chiefly in substitutional solid solution, replacing Fe^{++} and Mg^{++}. Its presence in the clay minerals is not quite clear. Probably, a considerable amount might occur in mineral fragments, while Sc^{+++} might be capable of replacing Mg^{++} in magnesium rich clays, or on the other hand, it might be adsorbed.

SUMMARY.

Using a spectrochemical method, a description of which is given, thirty-four clays were analysed for their trace elements. The results of the analyses are tabulated. The presence of trace elements is discussed generally, with particular reference to the common occurrence of Tl, Ga, and Sc in clay minerals.

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THE ORIGIN OF THE ECCA FIRECLAYS IN THE TRANSVAAL

BY

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In a previous paper some theories regarding the origin of these rocks have been discussed (Bosazza, 1943), and the time is now opportune to expand and revise those hypotheses. utilising the theory of Continental drift, now attaining the status of a principle, as set forth by Dr. du Toit (1937) in his great work, "Our Wandering Continents."

Pre-Karroo Conditions.

For the details of local conditions, the physiography of the peneplain itself and the condition of the floor, attention must be given to the Dwyka tillite and to its floor where it is exposed. From this emerges the conception of a vast peneplain with a great variety of soils. some leached to white clays such as are found to-day in the coastal belt from East London to Riversdale; others of much more usual types derived by the weathering of granites, dolomitic limestones and shales. Probably the topography of this peneplain was not very different from that of the thin blanket of rocks covering it to-day. The leaching of a shaley rock to a white residual kaolin has been reported in a previous paper (Bosazza. 1943). From the results incorporated in a more comprehensive work on the clays of the Witwatersrand area (Bosazza, 1941), it is evident that in the granite area to the north of the Far East Rand the weathering was very similar to that found to-day, and must have been largely the result of activity in pre-Karroo times.

The Ice Age.

While the continent was covered by the ice sheet, the disruption of the rocks below continued, being mainly confined to mechanical disintegration due to the low temperatures and, at this stage, to the small amount of organic activity. As the continent drifted, not necessarily in a regular direction or at the same rate, the climate varied from an extreme Arctic to a cold or even warm temperature. Fluvio-glacial bodies of water were formed, and in the Witwatersrand area the deposition of the conglomerate facies of the Dwyka Tillite took place. The peneplain was an inhospitable land, wind-swept and forlorn, with

little or no vegetable life of the higher forms. It is possible that while the conglomerate was being laid down, the deposition of fireclays was taking place elsewhere, and there is evidence in the conglomerate at Boksburg of some re-working, as pointed out by Dr. L. C. King.

Ice floes covered the shallow lakes and streams for the greater part of the year, and hence the oscillations of wind are not recorded in these shallow-water deposits. The stretches of water were broken by islands of harder rock; for example, the quartzites of the Pretoria Series and in the dolomitic limestone plains the chert horizons caused damming up and led to shallower conditions locally.

The flour produced by the grinding of the granite outcrops, and the white residual soils were deposited under these conditions. In some cases yellow clays were the main phase, later to be deprived of the iron and manganese oxides, and resulting in fireclays in juxtaposition to ferruginous epigenetic concretions. Organic matter and salts in the poorly drained basins resulted in the deposition of very fine-grained clays in shallow water. The previous postulation that highly saline waters were responsible for the coagulation of the fine particles is not now considered necessary, and is therefore abandoned (Bosazza, 1943). Photosynthesis was restricted by the ice covering and probably by the turbidity of the water, as suggested by Dr. du Toit to me in a private communication.

On the Dolomite plains the deposition of the fireclays (and the less refractory types as well) was accompanied by the subsidence of the limestones due to solution along the joints and the formation of cavities. This solution was largely controlled by the chert horizons, the Giant Chert being the most important. Faulting such as the Bank Fault on the Far West Witwatersrand also played some part in the distribution of ground waters during these times. Hence the occurrence of deposits of clays very close to chert outcrops and on high ground—for example, at Olifantsfontein, Kaalfontein and Rietfontein No. 9, West Witwatersrand, and at Lawley. Intrusive sheets in the Dolomite in the Pretoria district may also be the cause of such deposits. There may be many more deposits than have so far been exposed.

The depth of water west of Lawley must have been greater than at Boksburg, due to several causes, namely, the actual land surface was lower, the Pretoria Series quartzites led to some damming up and subsequent lowering of the floor due to solution and loading. This is reflected in a much lower organic content of the clays of the same type at Boksburg or Heronmere. The total depth of water probably did not exceed about 60 metres.

At Boksburg it is evident that on the edges of the old lake the iron content is higher than in the deeper zones due to the

activity of organisms, mainly bacteria. Bacterial activity was greatest in the calmer deeper water phases, and the temperature was also much higher due to thermal currents from warmer zones or else to shelter from winds.

Inter- and Post-Glacial Ages.

The most important warmer phase deposit is that shown in the main clay pit of the Consolidated Rand Brick and Pottery Co. at Olifantsfontein. Here a black carbonaceous bed, almost approaching a coal in places, is exposed below the main bed of fireclay. Lesser beds are to be seen at Brakpan and on the Far West Witwatersrand, being only of the order of a few inches to a foot thick.

Varving is not very distinct, although some instances reported by Mountain and Hodgson (1936) in Natal are of interest. The yellow clays above the fireclays in the Boksburg South and the Rangeview deposits are more like varved clays than any others noted in these deposits. Dr. L. C. King was willing to accept these as varved clays until more detailed work was done.

The non-plastic clays are difficult to account for unless a sub-aerial or aerial formation is assumed. The actual period of deposition was glacial, but the conversion from the original material to the present hard clay may be post-glacial.

Discussion.

It will be noted that the previous theories of the formation of fireclays have been accepted in part. Greaves-Walker (1939), has summarised most of the papers on the subject. In the present paper it is accepted that the fireclays have been partly transported as such and partly altered after deposition. The details from which these assumptions have been made are given at length in my thesis entitled " The Petrography and Petrology of South African Clays." South African fireclays, at present being exploited, are not the seat earths of coals, and hence Grabau's theory that fireclays are the soils of the coal measure vegetation, which removed the iron, alkalis, etc., does not appear to obtain in the case of these deposits.

All the characteristics of the rocks are in accord with the principle of continental drift. The environment of the clays can be much more easily deduced from palæogeographical synthesis than by detailed petrographic analysis. It is gratifying to find that the tediously and independently obtained analyses will only fit in with the conception of a drifting continent during and previous to their formation. For example. the detailed mechanical analyses of the fireclays show their extremely fine-grained nature with, however, very small amounts of colloids. In other words, they are the products of glacial grinding to flour

of the rocks beneath. The organic matter is typical of that found in the Arctic areas of to-day, being the resultant of the lower forms of vegetable and animal life of cold regions. The postulation of continental elevation and subsidence in order to explain all the variations found does not satisfy when the petrology of these deposits is considered. Although this work does not provide confirmation of the principle of a drifting continent, it is not easy to explain the data without assuming that the principle is fundamentally true.

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METALLIC POISONS; A SYSTEM OF ANALYSIS

BY

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Just as the great organic group of chemistry is treated much more systematically than its relation inorganic chemistry, in the same way the investigation of poisoning by organic substances can be said to have received more logical treatment than that meted out to cases of inorganic poisoning. The latter are on a very loose basis, most text books treating the problem more as if in cases of inorganic poisoning the identity of the poison concerned is known to the analyst before he starts his investigation. The main reason for this attitude when dealing with metallic and metalloid poisons is the fact, that once the organic tissues have been destroyed, the final solution is considered to be a simple solution ot metals and that therefore these can be determined by the usual text book methods. The amount of material available for toxicological analysis, however, is of necessity very limited, and when one adds the further disadvantage that the metal responsible for the poisoning will be present only in little more than traces, it is obvious that this viewpoint is incorrect.

When dealing with organic poisons, no analogy with ordinary organic mixtures is possible, and it was a very much felt need, which led Stas in 1850, to evolve for the first time a method of analysis, which later became famous as the Stas-Otto method, and which renders possible the detection of a very large range of organic poisons.

No such general system exists when one has to deal with cases of metallic poisoning. This attitude must be deplored and as in addition the old accepted systems of separation as well as the newer methods of microchemistry are inadequate, it has become necessary to treat the question of metallic poisoning investigation from a new standpoint, adapting the most suitable of the old and of the new processes.

In the last few years newer methods of separation have been evolved, but these have not come up to their early promises. One of these newer methods was the use of a chloroform solution of diphenyl thiocarbazone (dithizone for short), which has the property of extracting a series of metals from acid or alkaline solutions.

Wickmann (1939:66) showed that although the separation of different metals was largely governed by the pH of the solution, no clean-cut separation was possible due to overlapping. In spite of this drawback, however, the dithizone method of separation and determination can be used to a limited extent and does play an important part in toxicological investigation, although in a narrower sphere than was originally hoped for.

In devising a system of analysis, the great consideration is the number of metallic poisons which must be taken into account. Although their number is large, practical experience has shown that under South African conditions it is limited to fourteen. I may mention here that there is a great deal of difference in the types of poison mostly used in various countries. Whilst in South Africa arsenic and cantharidin are the most common poisons employed, in India, for example, arsenic and opium lead the way. It is obvious that such characteristics must be considered in the drawing up of any system of toxicological investigation. In South Africa one has to deal also to a very large extent with cases of native poisoning, and as any substance possessing emetic and purgative properties is much prized by the native as medicine, it is not surprising to find included in the native herbalist's outfit metallic salts like alum, copper sulphate and potassium bichromate, the two latter having the added attraction of colour.

For practical purposes we can therefore divide the poisonous metals into two groups.

A. Those which are commonly encountered in toxicological practice and are more or less toxic.

B. Those which we know to be toxic to a higher or lower degree but which have never, as far as we know, figured as a poison under South African conditions.

In the first group we have aluminium, antimony, arsenic, barium, bismuth, chromium, copper, iron, lead, manganese, mercury, thallium, tin and zinc. Although bismuth is not considered to be of importance as a poison, its presence must always be expected due to its extensive use as a constituent of the powders and mixtures given in cases of stomach disorders. Tin figures occasionally in undesirable quantities in canned food products, although seldom in fatal amounts. Zinc is included because in spite of its low degree of toxicity, poisoning by means of the concentrated zinc chloride solutions known to plumbers as "killed spirits" has occurred.

Under the second group all the other metals like cadmium gold, osmium, silver and so forth, are placed. Although used to some extent we have never encountered them in our investigations and, therefore, it was decided to leave them out of any general system, which should be based, after all, on practical considerations and not on theoretical possibilities.

Such a system is herewith presented. The first step in the chemical investigation of acute poisoning is the routine one of applying the Reinsch test to the minced organs, preferably the liver. If the copper strip thus obtained shows a darkening, or "silvering," the sublimate obtained by heating it in a small flat, hard, glass tube is examined under a microscope. Shiny globules show the presence of mercury, whereas arsenic is indicated by the formation of the characteristic octahedral or tetrahedral crystals of arsenious oxide. Although most text books state that the sublimate from antimony is amorphous, I have known it to take a crystalline shape very similar to that obtained from arsenic.

By passing a stream of sulphuretted hydrogen through the slightly heated tube, the presence of antimony can be confirmed by the formation of an orange colour, whilst arsenic shows up yellow. When the black deposit extends to the platinum wire as well, bismuth must be expected.

I—Reinsch Test Positive—A. Mercury Present.

If the preliminary test has shown the presence of mercury, it is necessary to use a special method for the destruction of the organic tissues, as mercury salts are too volatile for the usual methods of destruction. The method described by Winkler (1938, 220), consisting of depositing the mercury on zinc powder and its subsequent determination in an acid solution by means of a carbon tetrachloride solution of dithizone, has been found to be very satisfactory. Since copper and bismuth, when present in appreciable quantities, interfere, it is necessary to eliminate these metals. By the addition of either potassium iodide or sodium thiosulphate to the solution, bismuth and mercury complexes are formed, which are extracted by the dithizone, whilst copper is unaffected. Bismuth can be removed by allowing the original dilute acid solution to stand overnight, by which most of the bismuth is deposited as the basic salt.

B. Mercury Not Present.

If mercury is absent, the organic matter can be efficiently destroyed by digesting the organs in a Kjeldahl flask by means of boiling sulphuric and nitric acids. The solution thus obtained is transferred to a standard 100 ml. flask and made up to volume.

Barium.

As the barium will have been converted to the insoluble barium sulphate, this metal must be looked for in the deposit formed during the digestion of the organic matter, and which under our conditions consists mostly of silica. This deposit must be fused with a mixture of potassium and sodium carbonates, after which the barium can be determined by any of the common methods.

Arsenic.

If arsenic is present it is determined by the method of Green (1918, 539). This method still remains the simplest of all those suggested for the determination of small amounts of arsenic, and with a slight modification, including the use of a more dilute iodine solution, we have been able to determine amounts of arsenic of the magnitude of 5 micrograms arsenious oxide, which is usually sufficient for the estimation of arsenic in hair. It may be mentioned here that for the purpose of determining the amount of arsenic when only very small amounts of hair and nails are available, we have modified the Gutzeit method by making use of a solution of lead acetate instead of the common solid devices like lead acetate paper, and are now able to determine arsenic with a fair amount of accuracy when present in amounts as small as 0·1 microgram.

Antimony.

Antimony is determined by the method of Bamford (1934, 101), which depends on the measurement of the intensity of the orange colour produced by means of sulphuretted hydrogen in the presence of a protective colloid like gum acacia.

Bismuth.

An accurate method of determining bismuth is that of Mahr (1933, 161), which makes use of the thiourea-bismuth reaction.

II—REINSCH TEST NEGATIVE.

A. Reaction with dithizone in alkaline solution positive. A fresh aliquot of the solution is now taken, and after the addition of citric acid to the extent of 30 per cent., it is made alkaline to a pH of 9 by means of dilute ammonia. The solution is now shaken out with successive quantities of a chloroform solution of dithizone until no colour change takes place. This extract may contain bismuth, lead, thallium, tin or zinc.

Zinc.

The zinc can be recovered from the dithizone extract by shaking it out with a solution of potassium cyanide, which removes the zinc but leaves the other four metals combined with the dithizone. As it is rarely necessary to estimate traces of zinc, any of the standard methods can be employed for its determination.

If zinc is known to be absent, the potassium cyanide solution can be added directly to the alkaline solution, but in such event it is necessary to guard against the possibility of oxidation of the dithizone by the ferric iron present in the viscera, as the ferricyanide formed destroys the reaction capacity of the dithizone. This can be done most suitably through the addition of a few crystals of hydroxylamine hydrochloride to the solution

prior to the shaking out. This has an added beneficial effect, as it stabilises the type of dithizone complex formed. A red colour then indicates the presence of bismuth, lead, thallium or tin, and it therefore becomes necessary to separate these metals. The first step in this is to shake out the dithizone extract with a buffer solution of pH 3·4 which, according to Bambach and Burkey (1943, 904), removes all the lead. The author has found that this treatment also removes any thallium and some traces of tin. The latter can be removed again by shaking out the buffer solution with more dithizone solution. The complete separation of the lead and thallium on the one side, and of the bismuth and tin on the other has thus been affected.

Lead and Thallium.

The buffer extract is now made alkaline and re-extracted with dithizone. After the removal by distillation of the bulk of the chloroform, the organic matter is destroyed by means of boiling sulphuric and nitric acids, which leaves a residue of lead and thallium sulphates. After the addition of an equal volume of alcohol to the diluted solution, the lead sulphate is filtered off through a micro filter, which affords a complete separation between the lead and the thallium salts. (This separation is based on the unpublished method of separation in the determination of lead by Copeman.)

Thallium can then be determined in the filtrate by means of a standardised dithizone solution.

Lead is determined in the same way, after the insoluble lead sulphate has been redissolved by the use of an ammonium salt such as ammonium citrate.

Tin.

If it is desired to determine tin, this can be achieved by the use of any of the standard methods. Its separation from bismuth can be effected by making use of the fact that whilst the tin sulphides are soluble in yellow ammonium sulphide, that of bismuth is insoluble.

B. Reaction with dithizone in alkaline solution negative.

Another aliquot is now boiled with a few drops of nitric acid, in order to oxidise all the iron present, and is then made alkaline with ammonia. Should a strong blue colour develop, copper in appreciable amounts may be expected.

Copper.

Although it is rare to have to determine copper in toxicological investigations, its estimation is easily effected by the method of Haddock and Evers (1932, 495) using the reaction between copper and di-ethyl-di-thiocarbamate.

The addition of ammonia to the solution made from viscera always causes the formation of a precipitate which consists mainly of the phosphates of iron, calcium and magnesium. This masks the presence of chromium and aluminium, and for further tests it is necessary to re-dissolve it in dilute sulphuric acid, after washing it thoroughly with a 2 per cent solution of ammonium sulphate until free from chloride. I should mention here that if bismuth or tin are also present these should be removed either through precipitation with sulphuretted hydrogen or by extraction with dithizone as described above.

The re-dissolved precipitate should now be tested for aluminium, chromium and iron.

Aluminium.

The test for aluminium is the qualitative one devised by Hammett and Sottery (1925, 142), using the ammonium salt of aurine tricarboxylic acid. This test can be used quantitatively as well, but for most purposes of toxicological investigations the method of Monier-Williams (1935, 9), which utilises the reaction between aluminium and 8-hydroxy-quinoline, can be recommended.

Chromium.

Chromium can be determined by oxidising it to chromate by boiling the solution with sodium peroxide. The chromate, which is indicated by the formation of an intense yellow colour, can then be determined volumetrically, using for the titration 0·01N sodium thiosulphate. If the amount of chromium is very small, then the colorimetric method based on the colour reaction with diphenylcarbazide as adapted by van der Walt and van der Merwe (1938, 809) is advisable.

Iron.

Iron is a normal constituent of the organs, especially the liver, and from a toxicological viewpoint only very large amounts can have any significance. Hence the iron can be determined by any of the common titration methods.

Manganese.

Most of the manganese is precipitated as phosphate by ammonia, and by treating the re-dissolved precipitate with a persulphate in the presence of silver nitrate, the manganese is easily indicated through the formation of a violet colour. For a quantitative estimation it is advisable to take a new aliquot, and carry out the persulphate oxidation on the solution direct. The permanganate formed can then be estimated colorimetrically.

SUMMARY.

As under South African conditions, experience has shown that the number of metals encountered in cases of poisoning is

limited to fourteen, a system is herewith presented by which it is possible to treat the investigation logically.

In this system the Reinsch test is used to indicate the presence of antimony, arsenic, bismuth and mercury; a chloroform solution of diphenylthiocarbazone to show the presence of bismuth, lead, thallium, tin and zinc; and ammonia is used to separate the remaining metals, viz., aluminium, chromium, copper, iron and manganese, with the exception of barium, which is determined directly in the deposit formed during the destruction of the organic matter by means of boiling sulphuric and nitric acids. The methods of determination for each metal are indicated.

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A REVISION OF THE GENUS *AGROSTIS* LINN. IN SOUTH AFRICA

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In this paper an attempt is made to add a further contribution to the study of the anatomy of the leaves of grasses. The genus *Agrostis* Linn. was selected in view of its close affinity with the genus *Sporobolus* R.Br. which was dealt with in a previous paper (Goossens, 1938). Furthermore, it was thought that a revision of this genus is now much overdue as Stapf's classification (Fl. Cap. Vol. VII, p. 545) of its South African species is not only much out of date, but is also based on rather indistinct and vague external characters. It was thought that perhaps some of the anatomical features of full-grown leaves could, as in previous cases, be incorporated in a classification scheme of the available material of the genus.

The anatomy of the leaves was not studied in full detail, but rather to determine marked anatomical differences with a view to applying these, if present, taxonomically. Admittedly, ecological studies are also very necessary to determine to what extent the anatomical features which are to be utilised for diagnostic purposes are susceptible to modification through changes in the environment. Such a procedure is, of course, also applicable to the external morphological features. As the existing classifications of plants are mainly based on a study of the external features as exhibited by dried specimens gathered from different areas, it may be claimed that a similar procedure could also be followed in connection with the internal morphological features. The material placed at our disposal was gathered by various collectors from all parts of South Africa and also from Rhodesia. We were therefore enabled to investigate specimens from habitats differing widely from each other and representing different climatic and environmental conditions. Where possible fresh material was also studied.

Where possible, fully developed, more or less basal leaves of the types or co-types were studied. Where neither of these could be had, basal leaves of representative specimens were kindly supplied by the Director, Royal Botanic Gardens, Kew. This procedure served as a basis for further comparative study.

This study also enabled us to verify the existing external morphological descriptions and to make several changes in the

existing classification of the material of the genus. Three new varieties are described. A key for the classification of the species is also given.

For the history of the genus *Agrostis* Linn. our readers are referred to a concise account given by Hitchcock (1905) in his work on the American grasses.

We are very much indebted to the directors of the different South African herbaria for kindly placing their material of this genus at our disposal; to the Director of the Royal Botanic Gardens, Kew, for kindly supplying us with leaf specimens of the types, or co-types, and failing these, of representative specimens; and to Mr. C. E. Hubbard, of that institution, for his valuable notes and suggestions.

Material and Methods.

As explained above, we were compelled to rely mainly on the dried herbarium specimens which were kindly placed at our disposal. The only species of this genus represented in the Potchefstroom area is *A. lachnantha* Nees of which fresh material was studied.

As in the case of *Sporobolus* R.Br. (Goossens, 1938) different leaf samples were studied in order to investigate the variability of the chosen anatomical features within one and the same leaf, between differently placed leaves on the same plant, and between leaves of specimens representing different habitats. However, for reasons given in previous studies, it was found preferable to use full-grown basal vegetative leaves. In all cases the cross sections were cut about one cm. above the ligule as the anatomical features are best discernable here. This procedure is also recommended by Duval-Jove (1870), Burr and Turner (1933), Goossens and Theron (1934), Vickery (1935) and others. As pointed out by Mrs. Arber (1934), Miss Vickery (1935) and others culm leaves must be avoided.

As the leaves used were mostly dry, it was found necessary to boil them for a longer or shorter period, dependent on their thickness, to expel air and to soften them prior to cutting sections. The boiled leaves were preserved in boiled water in corked test tubes. This method gave the best results even after several months. It must, however, be kept in mind that by boiling the dried leaves it is quite possible that some of the tissues might not recover completely with the result that correct results might not be obtained.

The methods used in cutting, staining and mounting sections are similar to those previously described (Goossens, 1938).

The Anatomy of the Leaves.

On the whole the anatomy of the leaves of the different species of *Agrostis* shows a remarkable uniformity and consequently hardly any of the anatomical features were of diagnostic

value. The leaves are mostly flat and open, and consequently they are straight or slightly curved when seen in cross section. *A.eriantha* Hack., however, is an exception, for its leaves are fairly rigid and typically folded so that it appears ellipsoid or V-shaped when seen in cross section.

The leaves very rarely exhibit a well-developed or distinct keel. They are of uniform thickness except towards the margins where they are much thinner and acute.

The adaxial surface is always prominently ribbed. On the whole the ribs are high, being deeper than wide, and having the tops rounded or flat.

The abaxial surface of the leaf is usually slightly undulating or flat. In some cases it is ribbed, but this is probably due to the chlorenchyma in the leaf having collapsed.

The chlorophyll tissue is distributed in the same places and in the same manner in all the leaves, forming an irregular tissue round and between the bundles. It is never arranged in a radiating manner as in most species of *Sporobolus* R.Br. (Goossens, 1938). In most species the chlorenchyma of dried leaves have a tendency to be contracted in H-shaped masses between the bundles. Its cells, too, are irregular in shape. Above and below the bundles the assimilating tissue is interrupted by stereome strands. In some species, e.g., *A.barbuligera* Stapf, the chlorenchyma shows a tendency to break up forming lacunae. It is, however, not such a consistent character as in the case of *Sporobolus pyramidalis* Beauv. and *S.capensis* (Willd), Kunth (Goossens, 1938) and can therefore not be used for diagnostic purposes.

The mechanical tissue or stereome occurs uniformly in the different species and could consequently not be applied taxonomically as Goossens (1938), Theron (1936) and Fisher (1939) were able to do.

In no case was any colourless tissue found in any part of the leaf. Its absence or presence could therefore not be used to the same advantage to distinguish between species as Goossens (1938) and Fisher (1939) were able to do.

All the bundles have the typical monocotyledonous structure and are surrounded by a double bundle-sheath. The inner is very conspicuous and typically and extensively thickened. The outer, consisting of thin-walled, isodiametric, parenchymatous cells, is not always very distinct. Fisher (1939) was able to distinguish between round and triangular bundle-sheaths as seen in cross section. She found these useful for diagnostic purposes, which, however, was not the case in the genus under revision.

Motor cells occur in groups of three to five (rarely more) cells between the ribs on the adaxial side of the leaf. They are not always clearly distinguished from the surrounding epidermal cells. They are more or less pear-shaped. It was not possible to

use the position and arrangement of the motor cells for classification purposes as Goossens (1938), Fisher (1939) and Theron (1936) were able to do.

As seen in surface view the epidermal cells between the bundles differ in some respects from those lying above the bundles. On the whole those between the bundles are thin-walled, large and often much swollen. Large, long cells very often alternate with one or a pair of short cells. The short cells may be round or oval in shape. The oval cells usually bear asperites. Rows of stomata also occur in this region.

The cells in the region over the bundles are smaller, narrower and much more thickened and their walls are often sinuate. Long and short cells also occur here. In the case of *A.eriantha* Hack. the short cells occur in pairs of which one has a dense content. According to Fisher (1939) and others such cells are suberised, while the other cells contain silica. The long cells often bear asperites which Fisher (1938) calls ' bulbous hairs.' The arrangement of the epidermal cells varied so much that it could not be used for diagnostic purposes.

General Results.

In his revision of the South African material of this genus, Stapf (Fl. Cap. Vol. VII, p. 545) recognises seven species. In his systematic key to the species he stresses such features as length of spikelet; absence or presence of an awn on the glumes; number of nerves per lemma; form of the panicle; absence or presence of an awn on the lemma; the position of the awn on the lemma; and the absence or presence of a definite prolongation of the rhachilla.

Superficially *A. subulifolia* Stapf appears to be a distinct species, but on closer study of the material which Stapf referred to this species we came to the conclusion that it is only a growth variation of *A.bergiana* Trin. Features such as colour, form of panicle, etc., are very variable and consequently unreliable characters. It is certainly not warranted to establish a new species on such characters. Even the anatomy of its leaves support our conclusion. Stapf had only seen a very limited number of specimens of *A.bergiana* Trin., and this probably led him to consider it as a distinct species. He was not in a position to study the many transitional growth forms of this species. We have very little doubt that *A.bergiana* Trin. is composed of a great variety of growth forms, extreme forms being linked by intermediate forms. It must be admitted with Hitchcock (1905) that it is true that specimens representing the extremes of certain groups seem distinct, but an examination of a large series of specimens often shows that the extremes are connected by numerous intermediate specimens.

Up to the present *A.suavis* Stapf (based on *Medley Wood*, 8913) and *A.eriantha* Hack. (based on *Schlechter*, 4144 and 4052)

have been considered separate species, but on studying the external morphology as well as the leaf anatomy we concluded that they are identical. It has since been brought to our notice that Schweickerdt (1938) had arrived at a similar conclusion *A.eriantha* Hack., being the older name, is retained and *A.suavis* Stapf sunk under it.

In a letter to us, Mr. C. E. Hubbard pointed out that Buchanan's specimen number 286 from Rietvlei, which forms the type of *A.papposa* Mez, is now *A.Huttoniae* (Hack.) Hubbard.

In the Kew Index *A.albimontana* Mez is mentioned as occurring in South Africa. The description in Fedde, Repert. XVIII. 3 1922 is based on a specimen collected by Galpin (probably his number 6911) from the Wittebergen. Galpin's 6911 undoubtedly belongs to *A.bergiana* Trin., so that the specific name, *A.albimontana* Mez, cannot be retained.

It was possible to segregate three new varieties, viz., *A.barbuligera* var. *longipilosa*, *A.eriantha* var. *planifolia* and *A.lachnantha* var. *glabra*.

As in the case of *Sporobolus* R.Br. (Goossens, 1938), it was possible to divide the South African species of *Agrostis* Linn. into two distinct sections based on the presence or absence of a produced rhachilla. It was found that Hitchcock (1905) had already completed such a division. He adopted the name *Eu-Agrostis* for those without the rhachilla prolonged and *Podagrostis* for those with the rhachilla produced.

Concerning the rhachilla and the structure of the spikelet, *Agrostis* shows affinity with *Sporobolus*, e.g. its lemma is three-nerved as in the latter genus. It remains an open question whether such resemblances should be looked upon as mere evolutionary trends which appeared simultaneously in different genera or as showing relationship.

Generic Description.

Vegetative features: Annual or perennial, varying in habit. *Culms* 2- to 9-noded, 7 to 120 cm. high, 0·75 to 3 mm. thick, erect or geniculately ascending, with the lower nodes often rooting, smooth or slightly striate or more or less rough below the nodes. *Leaves* 3·5 to 30 cm. long, narrow, flat or rarely folded, smooth or more or less scabrid, acuminate; ligule hyaline to scarious. *Panicle* usually branched, dense or spreading, rarely spike-like; spikelets usually numerous, up to 6 mm. long.

Floral characters: *Spikelets* small, linear-lanceolate to oblong-lanceolate or oblong, often gaping, more or less laterally compressed, awned or awnless, pedicelled in open or contracted panicles; rhachilla disarticulating above the glumes, not pro-

duced above the lemma, rarely produced and then as a mere point or a short bristle, glabrous or villous, rarely bearing a second rudimentary or imperfect floret. *Flower* 1 (rarely 2), shorter than or almost equalling the glumes. *Glumes* persistent, equal or sub-equal, usually linear-lanceolate or lanceolate and acute, rarely narrow and oblong, awnless or rarely awned, usually membranous, 1- (rarely 3-) nerved, keeled. *Lemma* broadly oblong, ovate-lanceolate, oval or elliptic when spreading, obtuse, thinner in texture than the glumes, usually membranous, hyaline, smooth or hairy, 5- (rarely 3-) nerved, with the side nerves often excurrent into mucros, awned from the apex or from below the apex or from the base. *Pale* as long as or more often shorter than the lemma, rarely very short or absent, 2-nerved or nerveless, hyaline and thinly membranous. *Lodicules* 2, lanceolate or oblong, thin, hyaline. *Stamens* 3. *Ovary* smooth; style distinct, very short, with plumose stigmas. *Grain* free and included between the slightly changed lemma and pale, oblong or more or less elliptic, grooved at the apex; embryo short.

KEY TO THE SPECIES.

Section I.—*Podagrostis* (Hitchc.), rhachilla produced.

Glumes distinctly awned . . . . 1. *A.polypogonoides*.

Glumes awnless, rarely mucronate.

Lemma 5-nerved.

Lemma awned from the middle or above the middle; rhachilla at least ⅝ of the lemma; lemma densely hairy: abaxial surface of leaf prominently ribbed. 2. *A.Schlechteri*.

Lemma awned from near the base; side-nerves excurrent into short awns or mucro's; rhachilla up to ⅓ of the lemma.

Lemma more or less glabrous . . . . 3. *A.barbuligera*.

Lemma densely hairy. 3 *A.barbuligera* var. *longipilosa*.

Lemma 3-nerved; callus as long as or longer than the lemma; lemma slightly hairy or glabrous . . . . . . 4. *A.Huttoniae*.

Section 2.—*Eu-Agrostis* (Hitchc.), rhachilla not produced.

Perennial grasses.

Lemma 5-nerved, if rarely 3-nerved then awned from the middle with a short dorsal awn or mucro.

Panicle open or spreading, not spike-like.

Callus minutely bearded; awn not longer than the lemma . . . . 5. *A.bergiana*.

Callus densely bearded; awn far exceeding the lemma.

Callus hairs up to ⅓ of the lemma; leaves filiform, oval as seen in cross section . . . . 6. *A.eriantha*

Callus hairs about ½ the length of the lemma; leaves flat, not folded . . . . . . 6. *A.eriantha* var. *planifolia*.

Panicle contracted and spike-like.

Lemma awned.

Lemma awned with a long and often curved basal awn; pale much shorter than the lemma; panicle elongated; plants large . . . . 7. *A.natalensis.*

Lemma awned with a short apical awn; pale about as long as the lemma; panicle small, oblong; plants small . . . . 8. *A.griquensis.*

Lemma awnless, obtuse, 5-denticulate; panicle densely contracted and lobed; glumes shortly mucronate. . . . 9. *A.semiverticillata.*

Lemma 3-nerved, hairy, rarely glabrous with the callus sparsely hairy, often shortly awned from below the apex.

Lemma hairy . . . . 10. *A.lachnantha.*

Lemma glabrous . . . . . . 10. *A.lachnantha* var. *glabra.*

Small annual grasses. . . . . 8. *A.griquensis.*

The abbreviations used in the following lists of the distribution of *Agrostis* spp. in South Africa are:—BLFU.—University College of the O.F.S., Bloemfontein; CTM.—South African Museum, Capetown; GRA.—Albany Museum, Grahamstown; K.—Kew Herbarium; KMG.—McGregor Museum, Kimberley; NH.—Natal Herbarium, Durban; NU.—Natal University College, Maritzburg; PRE.—National Herbarium, Pretoria; PUC.—University College, Potchefstroom; TRV.—Transvaal Museum, Pretoria. (Chronica Botanica, 1939).

1. **A.polypogonoides** Stapf, in Dyer. Fl. Cap. **vii,** 549.

CAPE PROVINCE: Drakenstein Mts. *Tyson* 824, CTM. 12725; Villiersdorp, *Schlechter* 9915, GRA.; 3797 TRV.

This species exhibits constant vegetative, floral and anatomical features. Stapf, *loc. cit.*, remarks that it approaches the genus *Polypogon* Desf. closely, differing from it only in habit and the absence of an apical sinus in the persistent glumes.

2. **A.Schlechteri** Rendle in Journ. Bot. 1899. 380; Stapf in Dyer, Fl. Cap. **vii,** 762.

CAPE PROVINCE: French Hoek, *Schlechter* 10274, K., GRA, K.; Villiersdorp, *Schlechter* 9909, PRE., GRA.; Ceres, Lakenvlei on the Matroosberg, *Phillips* 2101, CTM.; Genadendal, *Schlechter* 9840, PRE., GRA.

Schlechter 10274 is a co-type specimen.

3. **A.barbuligera** Stapf. in Dyer, Fl. Cap. **vii,** 548 (1900).

CAPE PROVINCE: Queenstown, Katberg, *Galpin* 8395, PRE., GRA.; Somerset East, Boschberg, *MacOwan* 2189, CTM.; Great Winterberg, *Galpin* 5607, PRE.; Barkly East, Doodmanskrans, *Galpin* 6914, PRE.

NATAL: Bergville, National Park, *Galpin* 10359, PRE., Estcourt, Giant's Castle Game Reserve, *West* 1621, NH., Estcourt, Summit of Bushman's Pass, *West* 1718, NH.

Co-type is *Galpin* 6914, PRE.

In the National Herbarium are two sheets bearing Galpin's 5607; on the one *A.bergiana* Trin. is represented and on the other *A.barbuligera* Stapf.

Stapf (Fl. Cap. vii. 549) considers this species to be related to *A.continuata* Stapf and *A.Mannii* (Hook. f.) Stapf (*Deyeuxia Mannii* Hook. f.). He points out that the prolongation of the rhachilla is in both cases similar to that of his *A.barbuligera* except for being glabrous in *A.continuata* Stapf. Furthermore, he points out that *A.Mannii*, which is more nearly allied, differs in the mode of growth and in having smaller spikelets and shorter panicle branches. For further remarks in this connection see also under *A natalensis* Stapf. Var. *longipilosa* Goossens et Papendorf. *Var nov.*

Affinis *A.barbuligera* Stapf sed spiculis conspicuis pilosis differt.

Natal: Qudeni, Qudeni Reserve, *Fisher* and *Schweickerdt* 25 NH.

4. **A.Huttoniae** (Hack). Hubbard in Fl. Trop. Afr. X, 172 (1937) (in clavi).

Synonymy: *A.papposa* Mez in Fedde Rep. XVIII. 2. (1922). *Calamagrostis Huttoniae* Hack. in Records Albany Mus. I. p. 113 (1904) and 340 (1905).

TRANSVAAL: Pretoria, Waterkloof, *Mogg* 15610 PRE.

NATAL: Estcourt, Bushman's River Pass, *West* 1656, NH., Qudeni, 15 miles from Ekombe on the way to Nqutu, *Fisher* and *Schweickerdt* 125, NH.; Lidgetton, *Mogg* 1377, PRE., Rietvlei, *Buchanan* 286, NH.

BASUTOLAND: Leribe, on slope of ravine, *Dieterlen* 975, PRE.

CAPE PROVINCE: Kokstad area, Mt. Frere, *Schlechter* 6409, GRA.

This species comes close to *A.lachnantha* Nees, differing from it in that the callus is long and hairy and in possessing a distinct rhachilla. Stapf (Fl. Cap. vii. 550) includes specimens of this species under *A.lachnantha* Nees.

5. **A.bergiana** Trin., in Gram. Unifl. and Sesquifl. 203; Stapf in Dyer, Fl. Cap. vii. 547.

CAPE PROVINCE: Cape Peninsula, Constantia Nek, *Wolley Dod* 2086, PRE., Platteklip, *Zeyher*, CTM. 19412, Devil's Peak, *Zeyher*, CTM. 19415, *Adamson* 1387, PRE., Between Hout Bay and Wynberg, *Drege*, CTM. 19411; Kirstenbosch, *Wolley Dod* 2384, PRE.; Stellenbosch Flats, *Duthie*, PRE.; Bainskloof, *Schlechter* 9200, GRA.; Clanwilliam, *Leipoldt* 343, CTM.; Koude Bokkeveld, *Schlechter* 3844, TRV.; *Schlechter*, 10081, PRE., GRA.; Koude River, *Schlechter* 9596, PRE., GRA.; Riversdale, *Schlechter* 1940, CTM., GRA.; George, *Schlechter* 2344, GRA.; Keurbooms River, *Schlechter* 5941, GRA.; Plettenberg Bay, *Rodgers* and

Smart 26055, TRV.; Humansdorp, Slang River, *Spearman* 21, PRE.; Genadendal, *Schlechter* 3602. TRV.; *Schlechter* 9808, PRE., GRA.; Grahamstown, Yarrow, *Burtt-Davy* 11615, PRE.; Hoffman's Bosch, *Butten* 1050, GRA.; Kingwilliamstown, *Sim* 867, 2817, GRA.; Somerset East, *Gill College Herb.* 1904, GRA.; *McOwan* 1321, CTM.; Barkly East, Doodmanskrans, *Galpin* 6911, PRE., NH., CTM.; *Galpin* 6910, 6913, PRE.; Great Winterberg, *Galpin* 5607, PRE., GRA.; Queenstown, Katberg, *Galpin* 8396, PRE., GRA.; without precise locality, *R.P.*, PRE. 27258.

NATAL: Qudeni, epiphytic on Cyathea Dregei, *Fisher* and *Schweickerdt* 11, 81; Estcourt, Bushman's River Pass, *West* 1664, all NH.; Balgowan, *Mogg*, PRE. 27257; Wahronga, Merrivale, *Littlejohn*, PRE. 8090; Underberg, in cultivated lands, *McLean* 784, PRE, NH.; Mooi River, South Downs, *Burtt-Davy* 10246, PRE.

BASUTOLAND: Mafeteng, Govt. Nurseries, *Dieterlen* 1366, PRE.; Leribe, *Dieterlen* 842, PRE., NH., CTM.; Malutis Mts., Ketane Valley, *Dieterlen* 1115, PRE.

TRANSVAAL: Ermelo, Spioenkop, *Burtt-Davy* 9233, PRE., without precise locality, *Carter*, NH 12619.

This species includes a large number of forms which are very variable in habit and cannot be distinguished as separate species or varieties. The extreme forms, although very distinct, are linked up with transitional forms. There are small forms like *Schlechter* 2344 and large forms like *Dieterlen* 1366. Extreme forms like *Burtt-Davy* 10246 and *Leipoldt* 343 are linked up with such intermediate forms as *Adamson* 1387 or *McLean* 784. *Fisher* and *Schweickerdt* 11 and 81 are also small forms often growing as epiphytes in forests. *Galpin* 6911, *McOwan* 1793, *Sim* 2817 and *Dieterlen* 842 also constitute an excellent series of intermediate forms.

Schlechter 2344 bears the name **A.bergiana** var. *mutica* Hack. We were, however, not able to get the description of this and neither were we able to find any character which separates it from other specimens of this species.

Stapf (Fl. Cap. vii. 547) mentions var. *laeviuscula* and describes it as follows: "leaves almost smooth; blades glaucescent, the upper spreading at right angles; panicle straight, very divaricate, longest branches one inch long, rarely longer; spikelets a little over one linn long; pale as long as or slightly longer than the valve." He mentions no specimen for this variety, and neither were we able to find a single specimen to agree with this description.

Stapf (in Kew Bull. 1910, p. 130) describes *A.subulifolia* as a separate species, but we failed to find any feature in support of his viewpoint. The specimens quoted under his species are therefore transferred to *A.bergiana* Trin.

According to the Kew Index *A.albimontana* Mez. (in Fedde Rep. 18. 3 (1922)) occurs in South Africa. According to Mr. Hubbard the description of this species is based on a specimen of Galpin from the Wittebergen, most likely *Galpin* 6911. If this is the case we have to admit that we failed to find any feature distinguishing it as a separate species from *A.bergiana* Trin.

Since coming to this conclusion it was brought to our notice that Schweickerdt (1938, p. 199) found that Mez (loc. cit.) based his species on *Galpin* 6911 and on comparing this specimen with the type of *A.subulifolia* of Stapf, he concluded that they belonged to the same species and referred Mez's species to that of Stapf As pointed out above we did not feel justified in upholding *A.subulifolia* Stapf as a distinct species.

According to Stapf (loc. cit.) *A.bergiana* Trin. is also represented in St. Helena (*Burchell* 39).

6. **A.eriantha** Hack, in *Vierteljahrsschr. Naturf. Ges.* Zurich, **49,** 172 (1904).

TRANSVAAL: Belfast, *Doidge* and *Bottomly* PRE., PUC.; *Collins*, TRV. 13902; Ermelo, Spioenkop, *Burtt-Davy* 9235; Ermelo, Nooitgedacht, *Potter* 1745; Kaapse Hoop, Duiwelskantoor, *Pole-Evans* 1007 (all PRE.); Mailaskop, *Schlechter* 4569, 14014, TRV.; Dullstroom, *Galpin* 12469; Chrissiemeer, Spring Grove, *Pole-Evans*, 1044 both PRE.; Middelburg, *Schlechter* 4052. GRA.; Johannesburg, *Hutton* 252, NH., CTM.; Johannesburg, Rietfontein, *Cohen* 794; Florida, *Hutton* 604, both PRE.; Pretoria, *Schlechter* 4144, NH., GRA.; without precise locality, *Pole-Evans* 3792, PRE.

NATAL: Van Reenen, *Wood* 8913, NH; *Bews* 226, NU.

We carefully-examined the type of *A.eriantha* Hack. (*Schlechter* 4052 and 4144) and of *A.suavis* Stapf (in Kew Bull. 1908. p. 227), viz., *Medley Wood* 8913, both morphologically and anatomically, and found that they agree in all respects. The types of these two species, therefore, belong to one and the same species. Hackel's specific name, being the older, has preference.

Since the completion of this research it was brought to our notice that Schweickerdt (1938, p. 199), on examining these types, had arrived at a similar conclusion.

Var. **planifolia** Goossens et Papendorf. *Var. Nov.*

A.erianthae Hack. affinis, sed differt in quo folium planum est et capilles calli usque ad dimidium lemmatis longes sunt.

TRANSVAAL: Irene, Doornkloof, *Pole-Evans* 666, PRE.

7. **A.natalensis** Stapf in Kew Bull., 1897, p. 290; Stapf in Dyer, Fl. Cap. vii. 548.

TRANSVAAL: Ermelo. Spioenkop, *Burtt-Davy* 9232; Lydenburg, Belfast, *Burtt-Davy* 1328; 1277; Chrissiemeer, *Pole-Evans* 1043; Piet Retief, Vroegeveld, *Pole-Evans* 1968; Nylstroom, Warmbaths, *Pole-Evans* and *Smuts* 685; Woodbush, Mogg 14713 (all PRE.).

NATAL: Howick, *Schlechter* 3816, TRV.; *Schlechter* 6794, GRA.; Umpumulo, *Buchanan* 159, NH.

The type of *A.phalaroides* Hack. (viz. *Schlechter* 6794) agrees in all respects with the type (*Buchanan* 159) of Stapf's species, and must therefore be considered synonymous with it. Stapf in an unpublished MS. came to a similar conclusion.

According to Mr. Hubbard (Fl. Trop. Afr. X. 176) *A.natalensis* Stapf differs from *A.continuata* Stapf in the culms which are five- to six-noded, the larger spikelets (5-6mm.) and the linear-oblong glumes. Stapf (Fl. Cap. vii. 549) points out that in his *A.continuata* the rhachilla is continued, but as we did not have the type or any authentically named specimens of this species at our disposal we were not able to verify this. Neither did Mr. Hubbard comment on it in his letter to us.

As far as the leaf anatomical features are concerned *A.natalensis* Stapf comes close to *A.lachnantha* Nees, while the position of the awn on the lemma, on the other hand, agrees very closely with that of *A.barbuligera* Stapf. It differs, however, from these two species in the character of the panicle and the minute pale.

The type specimen is *Buchanan* 159 in the Natal Herbarium and in the Kew Herbarium.

8. **A.griquensis** Stapf in Kew Bull., 1897, p. 290. Stapf in Dyer, Fl. Cap. vii. 546.

CAPE PROVINCE: Barkly West, Olienkop, *Ferrar*, PUC.; Holpan, *Acocks* 2466, KMG.

O.F.S.: Bloemfontein, near Tempe farm, *Potts* 2467, PRE.

Type specimen is *Burchell* 1863 in the Kew Herbarium.

9. **A.semiverticillata** (Forsk.) C.Christ. in Dansk. Bot. Arkiv. Iv. 3.12.1922.

CAPE PROVINCE: Cape Flats, Retreat Vlei, *Adamson* 1358, PRE.; Stellenbosch, near Sir Lowry's Pass, *Andreae* 63, PRE.; Cape Peninsula, roadside beyond Black River, *Wolley Dod* 2200, PRE.; Kirstenbosch, *Bolus*. 14684, GRA.; Elsenburg, *Marloth* 3044. PRE.; Cape Division, *Rogers* 2395, GRA.; near Monte Grand Canary, *Rogers* 2395, GRA.; Princess Vlei, *MacOwan* 1794, CTM.; Port Elizabeth, *Paterson* 3181, NH.; Britstown, *Wilman* 675, KMG.

TRANSVAAL: Pretoria, *Mogg* 14117; Apies River near Lion Bridge, *Smith* 1423; Prinshoff, *Pentz* H. 8634, (all PRE).

O.F.S.; Bloemfontein, in spruit near Victoria Park, *Moraile* 3520, PRE.

TEMBULAND: Cala, Convent, *O'Brien* 164, GRA.

In a letter to us Mr. C. E. Hubbard, of the Kew Herbarium, intimated that the type of this species is *Phalaris semiverticillata* (Forsk.) C.Christ. Stapf, loc. cit., describes it under *A.verticillata* Vill.

This species is easily recognised by its general growth habit, the form of the panicle and the awnless lemma. As in

A. polypogonoides Stapf the glumes are awned, but the awns are much shorter.

10 **A. lachnantha** Nees in Ind. Sem. Hort. Vratisl. 1834 and in Linnaea X. 115 (1836).

CAPE PROVINCE: Cape Town, Table Mountain at Wynberg Reservoirs, *Adamson* 1304; Table Mountain at Mt. Club. Hut, *Smuts* 723; Table Mountain, above Lion's House, *Pole-Evans* 493, all PRE.; Montagu, *Kensit*, GRA. 14706; between Ceres and Leeuwfontein, *Pearson* 3240, CTM.; Riversdale, *Schlechter*, GRA. 1921, CTM. 44860; Uitenhage, Zwartkops River, *Ecklon*, GRA. 1905.; *Ecklon*, GRA. 173; *Zeyher*, CTM. 12710; Mt. Hope, *Galpin* 5609, PRE., GRA.; Stutterheim, Fort Cunynghame, *Schonland* 12 and 44; Albany, Botha's River Valley, *Schonland* 4418 and 4421, all GRA.; Kingwilliamstown, *Sim* 5246, NH.; *Sim* 229 and 230, NU.; Somerset East, *McOwan* 1846, CTM.; Somerset East, Boschberg, *McOwan* 1667, PRE., GRA.; Kentani, *Pegler* 1384, PRE., CTM. and 2921, CTM.; Komga, *Flanagan* 1019, PRE., CTM.; Sunday's River, *Drege*, CTM. 19414; Upper Zwart Kei, GRA. 5609; Wittebergen, *Drege*, CTM. 19413; Middelburg, Grootfontein, *Gill* 10, PRE.; Bedford, *Gane* 156, GRA.; Springfields, *Paterson* 3300, GRA.; Murraysburg, *Tyson* 12457, TRV.; Barkly West, Newlands, *Paton* 4856, TRV., KMG.; Griquatown *Wilman* 4859; Kimberley, Kalkdrift, *Wilman* 2463 (both KMG.)

NATAL: Estcourt, Bushman's River, *West* 1627 and 1657, NH.; *Daly* 793, PRE., GRA.; Nottingham Road, Lynedock, *Bews* 228, NU; Molteno, near Railway, *Bews* 227, NU; Majoebanek, Sterkspruit, *Hepburn* 134, GRA.; Giant's Castle, *Symons* 294, TRV.; Umpumulo, *Buchanan* 280, NH.; Weenen, *Sharo* (*Wood* 8691), NH. 9097; Mooi River, *Mason*, NH. 9519; *Mogg* 3404 and 3314; Vryheid, *Galpin* 10228; Melmoth, Imfulazane, *Mogg* 6136; Dargle Road, *Mogg* 5722; Tweedie, *Mogg* 2722; Cedara, *Baker* H. 11494; Balgowan, *Mogg* 3538, (all PRE).

BASUTOLAND: Leribe. *Dieterlen* 197, PRE., NH., CTM.; Maluti Mountains, *Staples* 126, PRE.

O.F.S.: Senekal, Wonderkop, *Goossens* 835, PUC.; Senekal, Doornkop, *Goossens* 736, PRE., PUC.; Senekal, Ferrara, *Goossens* 962, PRE., PUC.; Rosendal, Rhebokkop, *Goossens* 1888, PUC.; Kroonstad, Bothaville, *Goossens* 1189, PRE., PUC.; Kroonstad, *Pont* 122, PRE.; Heilbron, Makouvlei, *Brandmuller* 4; Ficksburg, Rivenhill Farm, *Potts* 3675; Fauresmith, Bakbank, *Smith* 4621A; Fisher v. d. Merwe's Farm, *v. Breda* 48, (all PRE.); Rietfontein, *Rehmann* 3685, GRA.

TRANSVAAL: Potchefstroom, *Dippenaar* 260, PUC.; *Burtt-Davy* 1765, PRE.; *Papendorf* 548, PUC.; Krugersdorp, *Sellschop* 10, PRE.; Witwatersrand, Robinson Deep, *Cohen*

790, PRE.; Johannesburg, *Leendertz* 6063, TRV.; Witwatersrand, Canada Junction, *Cohen* 788, PRE.; Irene, Doornkloof, *Pole-Evans* 379, PRE., PUC.; *Pole-Evans* 562, PRE.; Pretoria Fountains Valley, *Verdoorn* 486, PRE.; Pretoria, *Leendertz* 3889, TRV.; *Stent*, PRE.; Pretoria, Klapperkop, *Mogg* 16198; Pretoria, Sunnyside, *Mogg* 16006, both PRE.; Pretoria, Hartebeestnek, *Burtt-Davy* 770, PRE.; P.P. Rust, *Leendertz* 6690, TRV.; Zoutpansberg, Entabeni, *Obermeyer* H. 31867, TRV.; Volksrust, Highlands, *Mogg* 7456; Nylstroom, *Burtt-Davy* 2081; Ermelo, *Burtt-Davy* 4165; Marico, Wonderfontein, *Burtt-Davy*, 7591; Lydenburg, Rooidraai, *Liebenberg*, 3491, (all PRE., the last-named also NH.); Carolina, *Pellisier*, BLFU, 4608; Modderfontein, *Haagner* 3786, TRV.; Maquabie, *Roberts* 5947, PRE.

RHODESIA: Salisbury, *Eyles* 2039, CTM.

SOUTH-WEST AFRICA: Waterberg, *Boss*, TRV. 35110; Ongeama, in the Nossob River, *Volk* 2294, NH.; Okosongomingo, near Otjiwarongo, *Volk* 2735, NH.

Var. **glabra** Goossens et Papendorf. *Var. nov.*

Affinis cum *A.lachnantha* Nees habitus, sed in respectu lemmae glabri et saepe cum duobus mucronibus ad apicem differt.

TRANSVAAL: Ermelo, Amsterdam, *Buchanan* H. 4331, PRE.
O.F.S.: Fauresmith, Veld Reserve, *Henrici* 1907 and 1909, both PRE.

CAPE PROVINCE: Kamiesberg, *Adamson* 1447, PRE.; Murraysburg, *Tyson* 554, NH.; Engcoba, *Flanagan* 2791, PRE.; Kenilworth, *Bolus* 15012, NH.; without locality, *Zeyher*, CTM. 17487.

SOUTH-WEST AFRICA: Waterberg, *Boss*, TRV. 36453.

All these forms of our variety are tall and rigid like *A.lachnantha* Nees, except *Flanagan* 2791 which is small and slender. Judging from the latter's habit and colour it probably grew under unfavourable conditions.

As far as size and habit are concerned *A.lachnantha* Nees is not nearly so variable as Stapf considers. It is an easily recognisable species with a characteristic panicle and growth habit. Drege's specimen from a cave in the Wittebergen is small and poorly developed and was described by Nees (Fl. Afr. Aust. 148) as *Podosaemum lachnanthum* var. *humile*. *Galpin* 5607 and 8396 were also erroneously identified as *A.lachnantha* var. *humile*. On closer examination they were found to belong to *A.bergiana* Trin. From this it is apparent that *A.lachnantha* Nees and *A.bergiana* Trin. are closely related.

According to Steudel *A.gymnostyla* Steud. in Syn. Pl. Glum. 1. 170 (*Podosaemum gymnostylum* Nees in Ind. Sem. Hort. Vratisl. 1850 and in Linnaea XXIV. 236, and *Mühlenbergia gymnostyla* Walp. in Ann. iii. 753) also occurs at the Cape. His

description is based on a cultivated specimen of unknown origin. However, Fenzl in Ind. Sem. Hort. Vindob. 1850, considers it to be identical with *Cinna mexicana* Beauv. and therefore does not belong to *Agrostis*.

SUMMARY.

1. The line of research started at this institution some years ago is continued.
2. The material studied and the methods adopted are discussed.
3. The anatomy of the leaves of the different species of *Agrostis* Linn. is discussed.
4. The general results arrived at out of the study are discussed. It was possible to segregate three undescribed varieties.
5. A description of the external morphological features of the genus is given.
6. A key to the species is put forward.
7. The different species as well as their distribution in South Africa are given.

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TRANSPIRATION STUDIES OF SOME NATAL MIDLANDS THORNVELD TREES.

BY

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With 5 Text Figures.

Read 3rd July, 1944.

This paper summarises the results of an investigation of the transpiration rates of a number of Natal thornveld plants. The plants used were *Acacia arabica Willd.*, *Gymnosporia buxifolia* Syzsyz., *Zizyphus mucronata* Willd., and *Randia rudis* E. Mey. *Acacia arabica* and *Gymnosporia buxifolia* are typical thornveld heliophytes. *Zizyphus mucronata* occurs either fully exposed to sunlight or under the shade of other heliophytes. *Randia rudis* is typically sciophytic, occurring as an under-shrub in the shade of *Acacia arabica* and other heliophytes.

Experimental Methods.

I. *Torsion Balance Method for Determining Transpiration Rate.*

In order that some idea might be obtained of actual transpiration rates under natural conditions, it was decided to determine transpiration in the field from the loss of water by small twigs detached from the selected plants. For this purpose a portable torsion balance was used, the balance being fitted into a case so that both pans and material were protected when readings were made in the open. The standard method of procedure was adopted.

As far as possible the twigs used were taken from branches exposed to full sunlight. As soon as a twig had been detached, its weight was determined and measurements of loss in its weight were taken at recorded intervals of approximately one minute duration over a period of about five minutes. When these readings had been taken, the leaves were removed from the twig and the stalk was weighed. By Subtraction of the weight of the stalk from the original weight of the twig, the fresh weight of the leaves was obtained. From the data *the transpiration rate in grams per gram fresh weight of leaves per hour* was calculated.

Stocker (Lundegardh, 1931) obtained good measurements of transpiration by weighing leaves and twigs on a balance at short intervals of time. He concluded that transpiration rate is more

significant when expressed in terms of unit fresh weight of the transpiring material than in terms of leaf area.

Test of the Reliability of the Torsion Balance Method of Determining Transpiration Rate.

1. Mathematical Test.—One hundred and five of the earliest sets of readings obtained by the above method, and representative of all trees for which transpiration was calculated, were chosen. Each set gave weights of a twig at approximately minute intervals over a period of about five minutes. In the case of each set, weight was plotted against time. Assuming that the points on each graph lie on a straight line, a straight line was fitted to the points by the method of least squares, as is shown in Fig. 1.

In order to determine the goodness of fit of this line to the points, the root mean square residual was calculated. The percentage number of tests in which the root mean square residual was less than a given number of units (1 unit=0·1 mgm.) was calculated, and is shown graphically in Fig. 2.

The average root mean square residual for all 105 tests was 7·7 units.

Since the torsion balance could be read accurately to 5·0 mgm., there was a mimimum experimental error of 5 units in every reading. Therefore there was an irreducible root mean square residual of 5 units. The average root mean square residual (7·7 units) was only 1·5 times as great as this value.

It could be considered reasonable to take a value of 10 units as an allowable root mean square residual, being only twice the value of the irreducible mimimum of 5 units.

From Fig. 2 it will be noted that more than one-half, i.e. 60 per cent., of the tests had a root mean square residual less than the average, and that in 75 per cent. of these tests, the points on the graph fitted the straight line with a root mean square residual of less than 10 units. Therefore, it can be concluded that in 75 per cent. of the tests the straight line gives a reasonable reflection of transpiration rate over the time interval in which transpiration was measured, i.e. there was no significant falling off or increase in the transpiration rate during that time interval; and that in 75 per cent. of the results obtained by the torsion balance method, the inclination of the straight line to the time axis was a good measure of the intensity of transpiration.

It is likely that if sets of readings from later experiments had been used, then, owing to greater experience in taking these readings, the percentage in which the root mean square residual was low would have been even greater.

2. General Reliability of Results.—Transpiration rate results obtained under similar experimental conditions were

consistent. This fact would substantiate any claim made for the reliability of the method.

II. *Investigation of External Factors Influencing Transpiration Rate.*

1. General Observations Regarding Wind, Light Intensity, and Clouding-over.—General notes on prevailing conditions with particular reference to wind, light intensity, and cloud-amount accompanied all measurements of transpiration rate.

During March and April, 1943, measurements of light intensity were taken at the Natal University College (Pietermaritzburg) by recording differences in the temperature of black and bright bulb radiation thermometers at hourly intervals, and also by means of a photo-electric light meter. No continuous records of light intensity could be obtained owing to the lack of the necessary apparatus. The influence of clouding-over at different times was also recorded, and it was observed that complete clouding-over cuts down light intensity to less than half that obtained on cloudless days.

2. Measurements of Temperature, Relative Humidity, and of the Saturation Deficit of the Atmosphere.—All measurements of transpiration rate were accompanied by readings of air temperature and of relative humidity taken by means of a wet and dry bulb whirling hygrometer. From these readings the saturation deficit of the atmosphere could be calculated in inches of mercury.

3. Soil Water Determinations.—No continuous record of soil water content at the sites of the trees being experimented upon was kept. On several occasions, however, samples of soil were collected adjacent to the roots of these trees, at about six inches below the surface of the soil. Soil water was calculated as a percentage of the weight of the fresh soil. The wilting coefficient of these soil samples was determined according to Briggs and Shantz's formula (Briggs and Shantz, 1912).

III. *Investigation of Internal Factors Influencing Transpiration Rate.*

1. Determination of Leaf Water Content.—All readings of transpiration rate were accompanied by determinations of leaf water content.

After the fresh weight of leaves had been obtained, they were placed in tubes, and dried to a constant weight in an electric oven at a constant temperature of 100°C. Leaf water content was then calculated as a percentage of fresh weight.

2. Measurement of the Degree of Stomatal Opening.—Molisch's injection method was used to determine the degree of stomatal opening (Maximov, 1929, p. 184).

Both paraffin and xylol infiltrated into the leaf when the stomatal aperture was still very small; alcohol entered only when

the aperture was already wide, and benzene at an intermediate stage. The time taken by the reagents to infiltrate through the stomata was also an indication of the degree of stomatal opening. A scale was devised expressing the width of stomatal aperture of the different species in micrometer units according to the degree of infiltration of the different reagents.

IV. *Investigation of Transpiration Rate Under Conditions of Controlled Water Supply.*

At certain stages during the course of this investigation, when attempting to interpret transpiration results obtained under natural conditions, it seemed desirable to compare these results with others obtained under conditions of controlled water supply.

1. Measurements of Rate of Water Loss of a Twig Supplied with Water.—In some experiments hourly measurements were taken of the amount of water given off by a cut twig the end of which was placed in a tube of water. This twig was ensured a constant supply of water.

2. Measurement of Transpiration Rate under Wilting Conditions.—A branch of the tree under observation was cut, and the end cut again under water in a beaker. It was then left standing in the beaker of water in a saturated atmosphere for 48 hours so that the leaves might become fully turgid. When this branch was removed from the saturated atmosphere, it was also removed from its supply of water in the beaker, and then clamped to a retort stand. Hourly readings were taken of the rate of transpiration of twigs cut from this branch.

Results.

It is impossible to discuss here the separate results of the fifty different experiments conducted during the course of this investigation. However, a careful analysis of the observations made, and of the facts disclosed, permitted of the following conclusions with reference to the transpiration behaviour of some Natal midlands thornveld trees.

Conclusions.

1. Early in the morning, when the stomata were practically closed, transpiration was slight. With increase in light intensity after sunrise, the stomata opened gradually, and transpiration rate increased.

2. There was often a decrease in transpiration between 07·00 and 09·00 hours. The reason for this requires further investigation.

3. When the saturation deficit of the atmosphere was relatively low, or when water supply was good, the rate of transpiration tended to reflect the direct influence of external physical factors such as temperature, relative humidity, and light intensity. This is shown in Fig. 3.

4. With high saturation deficit and low soil water content (conditions typical of warm winter days) transpiration rate fluctuated independently of changes in the external conditions.

(a) Transpiration rate was at a maximum either before or after saturation deficit reached its maximum. In the afternoon transpiration rate increased again with decreasing saturation deficit. See Fig. 4.

(b) Stomatal regulation of transpiration was very close. See Fig. 4.

5. In *Zizyphus mucronata* and *Randia rudis* there was apparently a closer relation between transpiration rate and leaf water content than in *Gymnosporia buxifolia,* where transpiration rate seemed to be practically independent of variation in leaf water content.

6. Leaf water content was, however, fairly constant, particularly under intense evaporating conditions. See Fig. 4.

7. When the water balance of the tree was apparently favourable, fluctuation in transpiration rate and leaf water content were somewhat related. See Fig. 5.

8. Under wilting conditions, leaf water content was maintained above a value of about 60 per cent. This was effected by reduction of water-loss during transpiration by stomatal closure.

9. In the early evening, and at night, stomata closed gradually, leaf water content increased, and transpiration rate was very low.

10. Maximum transpiration rates in summer were about twice as great as those obtained in winter.

11. On the coastbelt, values obtained for saturation deficit and transpiration rate were lower than those recorded in the midlands thornveld. The march of transpiration on the coastbelt then followed more closely that of external physical factors than was the case with the midlands thornveld plants.

ACKNOWLEDGMENTS.

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The writer wishes to express her indebtedness to Dr. A. W. Bayer, Professor of Botany, for his guidance and ready advice, and to Professor R. L. Rosenberg, of the Department of Mathematics, who worked out the mathematical test applied to the torsion balance results.

SUMMARY.

1. An account is given of the transpiration rate of some Natal thornveld trees, measured by the torsion balance method, and of the mathematical test of the reliability of this method. Other experimental methods used in the course of the investigation are briefly described.

2. From the results of these transpiration studies the following general conclusions are made:

(a) Under conditions of low saturation deficit or plentiful water supply, transpiration rate reflected the influence of the external factors of the environment, and tended to show some relation to leaf water content.

(b) Under conditions of high saturation deficit and limited soil water, reduction of transpiration was effected, in some cases by stomatal closure. Leaf water content remained fairly constant, and was independent of changes in transpiration rate.

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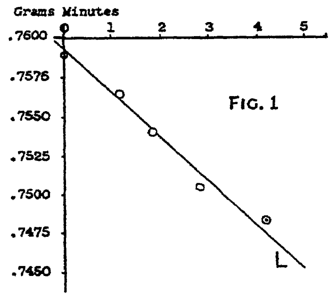
INDEX TO FIGURES.


Grams Minutes
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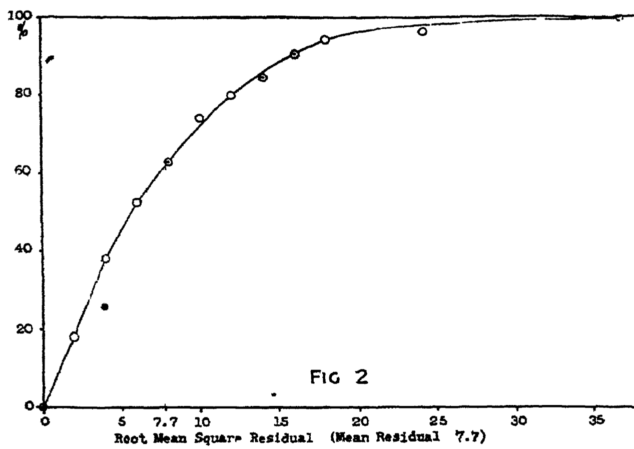
.7600
.7575
.7550
.7525
.7500
.7475
.7450
FIG. 1
L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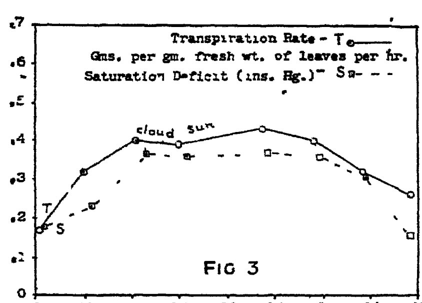
%
80
60
40
20
0
FIG 2
0 5 7.7 10 15 20 25 30 35
Root Mean Square Residual (Mean Residual 7.7)


Transpiration Rate - T
Gms. per gm. fresh wt. of leaves per hr.
Saturation Deficit (ins. Hg.) - S
cloud sun
T
S
.7
.6
.5
.4
.3
.2
.1
0
9 10 11 12 13 14 15 16 17
FIG 3

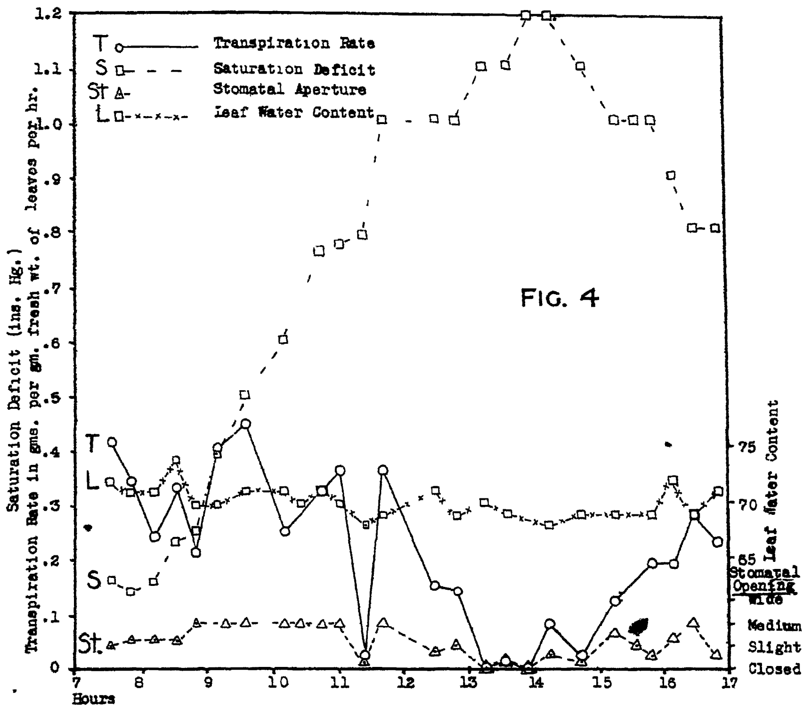

Transpiration Rate
Saturation Deficit
Stomatal Aperture
Leaf Water Content
Saturation Deficit (ins. Hg.)
Transpiration Rate in gms. per gm. fresh wt. of leaves per hr.
Leaf Water Content
Stomatal Opening
Wide
Medium
Slight
Closed
Hours

FIG. 4

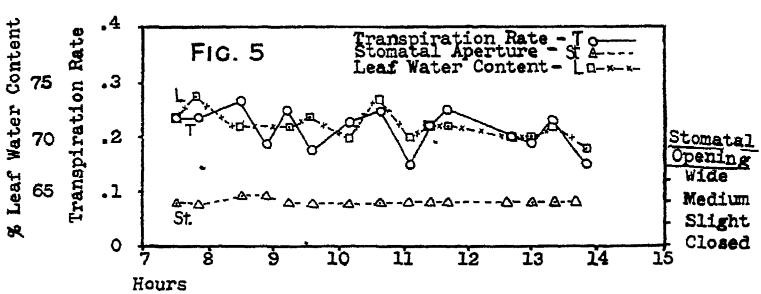

Transpiration Rate - T
Stomatal Aperture - St
Leaf Water Content - L
% Leaf Water Content
Transpiration Rate
Stomatal Opening
Wide
Medium
Slight
Closed
Hours

FIG. 5

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RESIDUAL EFFECTS OF FERTILISERS ON VELD HAY

BY

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TO

African Explosives and Chemical Industries, Ltd.

With 1 Text Figures.

Read 3rd July, 1944.

The experiments on natural veld being carried out on the Frankenwald Experiment Station of the University of the Witwatersrand have been described in a previous paper (1) and the results obtained over three seasons with beef cattle were published in 1940 (2). Subsequently, beef cattle were grazed in this experiment for another season, after which they were sold and were not replaced. Owing to the shortage of staff and the necessity in 1941 and 1942 of conserving fertilisers for food production, it was decided to stop grazing on this experiment and allow the grasses to grow for hay. It was also felt that advantage should be taken of the opportunity to determine the residual effects of the fertiliser treatments which had been carried out on this veld since 1933.

Description of Experiment.

In brief, the experiment consists of six treatments, each of four one-morgen plots. Five of the treatments are on undisturbed natural veld and one on planted Rhodes grass (*Chloris gayana*) and *Paspalum dilatatum* pastures. (One morgen of this treatment contains about 60 per cent. Digitaria spp.)

Two camps in each treatment on the veld and all camps on the Rhodes and *Paspalum dilatatum* pasture have been limed in the past, but the effect of the liming is not of such magnitude, so far as our experience has gone, as to affect the yields to any appreciable extent. The symbols designating the treatments are O, P, NP, NPK, N_3PK and N_3PK-F, where P represents an annual dressing of 400 lb. rockphosphate and superphosphate mixture per morgen annually in spring (10 per cent. water sol. P_2O_5, 17 per cent. citric sol. and 24 per cent. total P_2O_5). N represents one dressing of sulphate of ammonia at the rate of 200 lb. per morgen in spring (21·1 per cent. N) and N_3 three such dressings per morgen spaced over the growing season. K represents a dressing of 80 lb. chloride of potash per morgen annually in spring (60 per cent. K_2O).

The F in the N_3PK-F treatment indicates the N_3PK treatment on Rhodes and *Paspalum dilatatum* pasture.

The fertilisers applied in the 1941-42 season are given in Table I.

TABLE I. FERTILISER TREATMENTS IN 1941-42 SEASON.

Treatment.	Phosphate.	Potash.	Nitrogen.
O ...	—	—	—
P ...	400 lb. rock and super mixture per morgen 11/12/41 and 12/12/41	—	—
NP .	632 lb. nitrophosphate per morgen 27/9/41 to 10/10/41	—	50 lb. sulphate of ammonia per morgen along with N in nitrophosphate 27/9/41 to 10/10/41.
NPK ...	632 lb. nitrophosphate per morgen 30/9/41 to 15/10/41	80 lb. chloride of potash per morgen 17 to 21/10/41.	50 lb. sulphate of ammonia per morgen along with N in nitrophosphate 30/9/41 to 15/10/41.
N_3PK ...	632 lb. nitrophosphate per morgen 30/9/41 to 8/10/41	80 lb. chloride of potash per morgen 17 to 20/10/41.	50 lb. sulphate of ammonia per morgen along with N in nitrophosphate: 200 lb. sulphate of ammonia per morgen 9 to 20/1/42; 200 lb. sulphate of ammonia per morgen 12 to 26/2/42.
N_3PK-F	632 lb. nitrophosphate per morgen 27/10/41 30/10/41	80 lb. chloride of potash per morgen 27 to 30/10/41.	50 lb. sulphate of ammonia per morgen along with N in nitrophosphate: 200 lb. sulphate of ammonia on 2 camps 21/1/42 and 200 lb. on 4/3/42: other 2 camps 400 lb. on 17 to 21/2/42.

Nitrophosphate contained 11 per cent. water soluble: 13·5 per cent. citric soluble and 15·5 total P_2O_5 and 5 per cent. nitrogen, partly in the organic and the remainder in the inorganic form.

During the 1941-42 season all camps were mown four times, but the first mowing which took place during July and August, 1941, was not included in the calculations. This mowing was simply to trim the camps after the winter grazing. Subsequently, all the veld camps were mown after the *Themeda triandra* had ripened and shed most of its seed. This cut took place over the period 24/11/41 to 24/2/42, the last camps to be mown being

the control. All veld camps were mown again during the season and some were mown three times before the end of the growing season. The four N_3PK-F camps were each mown twice—once in January or February and again in late March or April.

In the 1942-43 season, when no fertilisers were applied, the veld camps were again mown after the *Themeda triandra* had ripened and shed most of its seed. All camps were thereafter mown a second time and the four camps of the N_3PK treatment and two of the NPK treatment were mown three times.

The four camps of the N_3PK-F treatment were mown in February and again in May.

No fertilisers were applied in the 1943-44 season and the first cutting of the veld camps was taken when the grasses were in full flower. The first cutting was therefore started in November and completed in December. The very wet spell experienced in February, 1944, interfered with the programme of mowing and the dry weather experienced in March and April followed by the early onset of winter in May reduced the amount of herbage in the late autumn. However, all camps, including the four N_3PK-F camps were mown late in February or in March and the camps of the N_3PK, NPK and N_3PK-F treatments were mown for the third time in April.

Determination of Yields.

After mowing, the hay was raked up as soon as it was dry enough and put in one heap in each camp. This heap was then protected with a tarpaulin until the hay could be taken to the stack.

No weighbridge was available for weighing the hay and it was therefore decided to stack the hay from each treatment in a circular round-topped stack and determine the volume and the weight at the end of the season. Hosterman (3) in 1931, published the results of a study of types of haystacks and density figures of several kinds of hay and it was felt that his formula for calculating the volume of a circular round-topped stack could be used as well as his figure for the density of "wild hay."

The formula used is volume $= (0{\cdot}04 \times \text{over}) - (0\ 012 \times \text{circumference})\ \text{circumference}^2$, where the "over" is the distance from ground level over the highest point of the stack to ground level on the other side. The density figures for "wild" hay given by Hosterman are 600 cu. ft. per ton for hay 30 to 90 days in the stack and 450 cu. ft. per ton for hay over 90 days in the stack.

The hay was therefore stacked in circular stacks with a diameter of 15 feet, except the N_3PK treatment which gave so much hay and consequently became so high that the diameter had to be increased to 20 feet. At the end of the season the yields were calculated and were thought to be high for the type of veld concerned.

After feeding hay to a group of steers during the winter the stack from the NPK treatment remained and it was therefore decided to determine its volume and its weight and thereby gain some information on the density of South African veld hay in stacks. The stack was measured on the 20th September, 1943, and gave a volume of 2,494 cu. feet. The first portion stacked had been in the stack by this date 259 days and the last portion 137 days, and taking Hosterman's figure of 450 cu. feet to the ton for hay over 90 days in the stack, the tonnage should have been 5·542 tons. On weighing the hay on a platform scale, however, the tonnage was found to be 4·582 tons, which gives a density figure of 550 cu. feet to the ton.

The hay was then re-stacked in a circular round-topped stack with a basal diameter of 15 feet and subsequently re-measured at intervals. Table 2 gives the data obtained in this connection.

TABLE 2. SETTLING AND DENSITY OF VELD HAY—FRANKENWALD.

Date.	Days from stacking.	Circumference feet	Average "over" feet.	Volume of stack in cu. feet.	cu. feet of hay per ton
25/ 9/43	0	55	45·75	3,539	796
25/10/43	30	55	38·75	2,692	606
26/11/43	62	55	37·25	2,511	565
28/12/43	94	55	38·5	2,420	544
26/ 1/44	123	55	36·25	2,390	538
25/ 3/44	181	55	34 0	2,118	476

It should be noted that for the greater part of this period the stack was covered with a tarpaulin weighing 101 lb. and thus there was somewhat greater compression than would be the case in uncovered stacks.

From these results it would appear that for veld hay composed mostly of *Tristachya hispida*, *Trachypogon plumosus*, *Digitaria tricholaenoides*, *Heteropogon contortus*, *Themeda triandra*, *Eragrostis nebulosa* and *E. chalcantha*, *Hyparrhenia hirta*, *Brachiaria serrata* and occasionally some *Cymbopogon excavatus*, the following figures should be used:—

Freshly-stacked hay	... ...	800 cu. feet per ton.
30 to 90 days in stack	... ...	570 ,, ,, ,, ,
over 90 days in stack	... ...	540 ,, ,, ,, ,,
over 180 days in stack	... ...	475 ,, ,, ,, ,,

These figures have been used in arriving at the yields of hay quoted in this paper.

During the 1943-44 season an opportunity was afforded of testing the above figures. Four camps of the above type of veld

were mown and the hay was weighed on a tripod with a steelyard in order to obtain some information on the variability of these camps. The first mowing took place in January and the second in April.

The hay from the first cut was stacked in a small circular round-topped stack on 25/1/44 and that of the second cut was placed on top of the stack to complete it on the 12th April. The first cut of hay had thus been stacked for 127 days and the second for 49 days by the 31st May, when the stack was measured. The measurements were: circumference 43·5 feet and " over " 34·63 feet, which gives a volume of 1,633 feet according to the formula already quoted. Assuming the proportion of the first cut of hay to have been five-eighths of the total and that of the second cut three-eighths and using the figures of 540 cu. feet per ton for hay in the stack over 90 days and 570 cu. feet for that less than 90 days, the total weight was found to be 5,926 lb. The actual weights were 3,846 lb. for the first cut and 1,973 for the second, giving a total of 5,819 lb. The difference between the calculated and the actual weight was thus 107 lb. or 1·8 per cent. which can be considered most satisfactory.

Hay Yields.

The hay yields obtained in the three seasons are given in table 3.

TABLE 3. HAY YIELDS ON VELD—FRANKENWALD.

Treatment.	lb. air-dry hay per morgen.			Increases over No-fertiliser.		
	1941-42	1942-43	1943-44	1941-42	1942-43	1943-44
O	1,628	2,018	2,072	—	—	—
P	1,382	1,788	2,200	−246	−230	+128
NP	1,812	2,362	2,726	+184	+344	+654
NPK	1,904	2,684	3,080	+276	+666	+1,008
N_3PK	4,184	3,584	3,366	+2,556	+1,566	+1,294
N_3PK-F ...	2,572	1,026	1,458	+944	−992	−614
Seasonal rainfall	25·27″	33·29″	34·92″ to end of April, 1944.			

Feeding Tests.

Eleven Hereford Afrikander steers were obtained in June, 1942, and these were used for a feeding test during the winter of 1942, They were weighed on the 8th, 9th and 10th of June, 1942, and then divided into two lots. One lot of five was fed hay from the N_3PK-F treatment and the other lot of six hay from the N_3PK treatment. Both lots also received grass silage *ad lib* and were allowed to graze for an hour a day, more or less, on a winter pasture consisting mainly of Tall Fescue grass. From the 7th September the hay was moistened with

molasses at the rate of ½ lb. per head and working up to 2 lb. daily per head.

The feeding test was concluded on 15/10/42 when the animals were put out on to the spring grazing. Table 4 summarises the results obtained. All weights are averages of three weighings on consecutive days at the same time before watering.

TABLE 4. FEEDING TEST ON STEERS—WINTER, 1942.

Steer No.	Hay fed.	Av. weight at commencement of test.		Av. weight after 96 days.		Gain over 96 days.
1	N_3PK	692	...	719	..	27
2	,,	701	...	754	...	53
3	,,	719	..	792	..	73
4	..	732	...	800	..	68
5	,,	794	...	876	...	82
6	..	910	..	923	..	13
Average	,,	758	...	810·7	...	52·7
7	N_3PK-F	813	...	867	...	54
8	,,	747	...	781	...	34
9	,,	782	...	802	...	20
10	,,	853	...	909	...	56
11	,,	695	..	745	..	50
Average	,,	778	...	820·8	...	42·8

Samples of N_3PK and N_3PK-F hay were taken daily and composite samples of these were sent to the Umbogintwini factory for analysis. The results were as follows:—

	N	P_2O_5	K_2O	Sol. Ash.
N_3PK	0·97%	0·38	0·97	3·6
N_3PK-F	0·92%	0·41	1·45	3·3

This feeding test confirms the conclusions reached in an earlier publication (2) that when this veld type received the same fertiliser treatment as the artifically established pastures it gave better results.

FEEDING TESTS IN 1943.

The same steers were used in a similar feeding test in the winter of 1943, but the animals were not necessarily in the same group as they were in the previous winter. Again they were fed grass silage *ad lib* in the morning, grazed for an hour a day approximately on winter pasture and were then fed the two kinds of hay moistened with molasses at night. The results obtained are shown in Table 5.

TABLE 5. FEEDING TESTS ON STEERS—WINTER, 1943.

Steer No.	Hay fed.	Average weight on 10/6/43.	Average weight on 4/8/43(1)	Loss per head over 56 days.	Average wt on 4/9/43(2)	Gain or loss over 31 days from 4/9/43	Total gain or loss over 87 days.
4	N_3PK	1,029	1,025	−4	1,019	−6	−10
5	,,	1,093	1,073	−20	1,065	−8	−28
7	,,	1,178	1,161	−17	1,152	−9	−26
8	,,	1,096	1,077	−19	1,070	−7	−26
10	,,	1,148	1,109	−39	1,104	−5	−44
11	,,	1,055	1,019	−36	1,023	+4	−32
Average	,,	1,100	1,077	−22·5	1,072	−5	−27·7
1	N_3PK-F	1,054	1,040	−14	1,040	0	−14
2	,,	1,083	1,062	−21	1,074	+12	−9
3	,,	1,098	1,084	−14	1,109	+25	+11
6	,,	1,190	1,150	−40	1,169	+19	−21
9	,,	1,135	1,094	−41	1,103	+9	−32
Average	,,	1,112	1,086	−26	1,099	+13	−13

(1) N_3PK-F hay from 1942-43 season came to an end on 4/8/43.

(2) N_3PK-F hay from 1941-42 season came to an end on 1/9/43.

As in the previous winter daily samples of hay were collected during June and July. At the end of July a composite sample of each was obtained and sent to Umbogintwini for analysis. The results of the analyses were as follows.

Hay.	Moisture.	N.	P_2O_5	CaO	K_2O	Sol. Ash.
N_3PK	10·5	1·52	0·31	0·39	0·82	2·6
N_3PK-F	10·5	0·80	0·35	0·48	1·10	3·2

These figures must be accepted with reserve for the N content of the veld hay in the 1942-43 season, without fertiliser, is higher than that of the previous season when fertiliser was applied. Also the fact that the N_3PK-F hay for that season came to an end a month before the end of the trial and we had to finish off with the previous season's hay from these plots makes the result unsatisfactory.

Discussion

With reference to the formula used for determining the volume of hay stacks and the figures for calculating the yields, it should be pointed out that the estimations necessary when portions of hay in the same stack have been stacked for different periods introduce opportunities for error. It is more than likely that the results would have been of greater accuracy had it been possible to have all the hay in any one stack of the same age.

The yields in Table 3 show firstly, the important effect of the seasonal rainfall on the yields of veld hay; for the yields in the no-fertiliser camps and those of the P, NP and NPK treatments are less in 1941-42 with fertiliser than in the two succeeding years without fertiliser. In addition to the increased

yields from rainfall, it is difficult to say to what extent complete rest from grazing may have influenced yields.

Another feature of great interest in the 1941-42 season with fertiliser, is the great increase given by the veld in the N_3PK treatment as compared with Rhodes and Paspalum receiving the same treatment.

The two seasons without fertiliser enjoyed good rainfall. Notwithstanding this fact which increased yields on the no-fertiliser treatment to just over a ton to the morgen, it will be noted that phosphate alone gave a depression in yield in two years and a slight increase in the third year. This confirms the findings of Trumble and Fraser on perennial indigenous Danthonia in Australia (4). These workers also record that pure Danthonia pastures without legumes, respond very little to superphosphate and this applies to purely gramineous pastures in general. These opinions are in accordance with our own experience.

The consistent increase given by the single N dressing in the NP and NPK treatments is noteworthy, in view of the relatively small dressing given up to the 1941-42 season, namely 200 lb. sulphate of ammonia (42·2 lb. N per morgen) once annually. Another point of interest is the rapid decrease in the response to the N_3 dressings as compared with the single dressing. This may not be unrelated to the change of grass species, which has occurred on all the camps getting the high nitrogen dressing.

Under grazing conditions in these experiments, the response to potash was so small as to be without significance, but in the two years without fertiliser, the response is consistent and of such magnitude as to appear significant.

The rapid drop in yield in the N_3PK-F treatment appears to indicate that these planted pastures must be kept at a high level of fertility if they are to be kept productive.

In general, the results show that on veld which has been fertilised for a period of nine seasons, the residual effects of the treatments are appreciable and significant, even in the second season after fertilising has ceased.

SUMMARY.

1. Hay yields over three seasons, on the first of which the camps were fertilised, are used to interpret the benefits of the fertilisers and their residual values, on pastures which had been fertilised for nine seasons in succession.

2. As it was not found practical to weigh all the hay, Hosterman's formula was used, together with some actual weights of our own hay, to arrive at figures combining time of settlement with volume and weight, in order to get reliable tonnage based on stack measurements.

3. On this basis, figures were found varying from 800 cu. ft. per ton for freshly stacked veld hay to 570 cu. ft. for hay stacked

30 to 90 days, 540 cu. ft. for over 90 days and 475 cu. ft. for over 180 days.

4. One lot of hay was actually weighed as stacked and later measured and the weight calculated, using the factors in 3. The difference between the actual weight and the calculation was only 1·8 per cent., which can be considered most satisfactory.

5. Feeding tests for two seasons on steers, one lot getting the veld hay and the other the hay from established pastures of Rhodes grass and *Paspalum dilatatum*, indicated that when the veld had received the same fertilisers as the established grasses, its feeding value was as good. This confirms the grazing data previously presented (2). There was little difference in chemical composition.

6. Hay yields from the two seasons, without fertiliser but better rainfall, were higher than those of 1941-42 with fertiliser but lower rainfall.

7. In two seasons the yields from the camps which had had phosphates were lower than those of the controls. This is in accordance with Australian experience on indigenous perennial grass without legumes.

8. Residual nitrogen has given the most consistent and highest increase in hay, and the lower dressing has been proportionately better than the higher one, and more lasting. This confirms our grazing experiments data, when the camps were actually getting nitrogenous fertilisers. After two years without fertilisers the yields from PNK almost equal those from the PN_3K camps.

9. Where potash was applied, there has been a consistent response of such magnitude as to appear significant. Under grazing conditions, on the other hand, this was not the case.

10. The rapid deterioration of the established pastures when not receiving fertilisers was most marked and indicates that such pastures must be maintained at a high level of fertility to be productive

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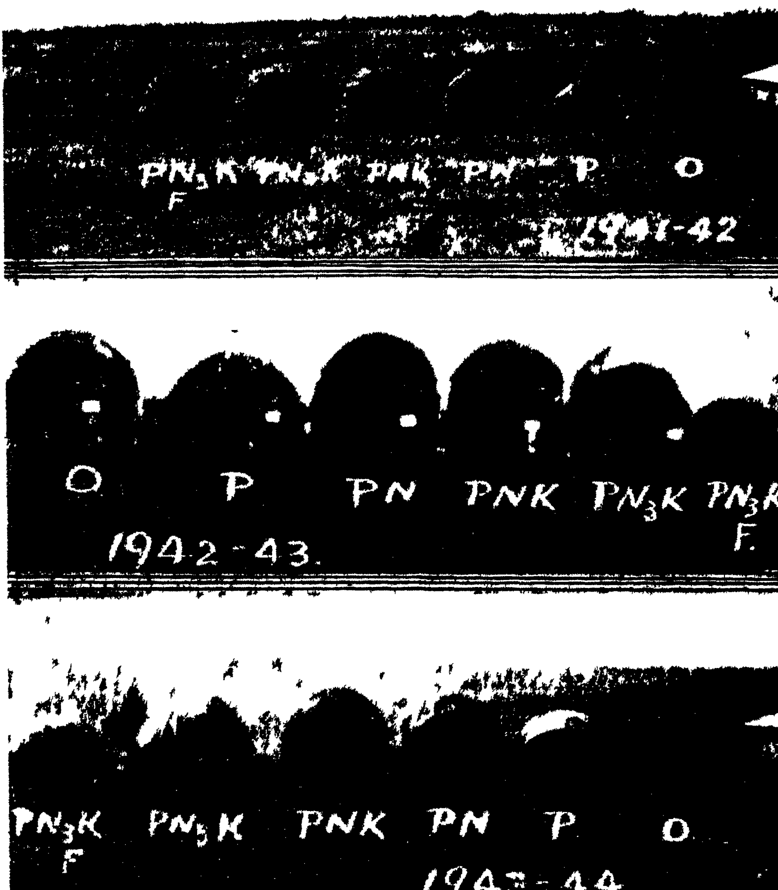
Fig. 1. A comparison of the hay yields in the three seasons reported in *Table 3*.

The decline of the Rhodes grass and Paspalum dilatatum hay PN_3K-F without fertiliser has been most marked.

Each stack represents the total yields from four 1 morgen camps of that particular treatment. The largest stack PN_3K in 1941-42 contains just under 8½ tons of hay. The amount of hay in stacks is usually over-estimated All stacks were 15 feet in diameter excepting the PN_3K, which in all three seasons was 20 feet.

FIG. 1



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THE EFFECT OF WILTING ON THE DIRECT ASSIMILATES OF LUCERNE AND OTHER FODDER PLANTS

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With 2 Graphs.

Read 3rd July, 1944.

Introduction.

The gardener, the agriculturalist and the scientist generally regard wilting as a misfortune for plants. It is only within the last 15 years that the Russian school under Maximow has defended the idea that wilting is a beneficial process which creates drought resistant plants. The first wilting may appear harmful, but it hardens the plant to endure further wilting without any ill effect. Little is known of the metabolism of the plants when they are wilting. It is known, however, that plants which are good fodder plants when fresh are often dangerous to stock when wilted—often—but not always.

The author has in the last few years paid particular attention to the changes in direct assimilates in fodder plants under the influence of wilting or of excessive water loss. The direct assimilates are certainly not the only constituents to be affected by wilting. Our present knowledge of the changes in metabolism and plant constituents due to water loss, wilting and drying is very fragmentary. It may be noted that in speaking of water loss, wilting and drying out, it is not meant that these processes follow each other in sequence; they may with soft leaves like those of the sunflower, but with small ericoid leaves of Karoo plants there can be appreciable water loss with no visible wilting, as the leaves contain much supporting tissue. In normal times the water loss of Karoo plants is replenished in the night, but not in times of drought, when the water loss increases day by day, week by week, until the leaves finally die. There are some Karoo plants with soft leaves which show signs of wilting, e.g., "bewerasie karoo" and *Sutera albiflora*. But on the whole these plants are scarce. Further investigations must show whether water loss without any visible signs of wilting and wilting have the same influence on metabolism. The metabolism of the plants under investigation must be determined both before and during wilting.

This paper only deals with starch, sucrose and reducing sugars.

Materials and Methods.

The plants investigated were selected from the point of view of their agricultural value as fodder plants which may prove poisonous at times. Two varieties of *lucerne*, *Tribulus terrestris*, *Algerian oats*, *Panicum minus var. planifolium* and *Pentzia incana forma* were investigated, all excellent fodder plants when fresh, but lucerne, Tribulus and Panicum at Veld Reserve, Fauresmith, having a doubtful record in causing bloating, dikkop or dikoor when wilted.

For *Pentzia*, fresh plants were sampled some 48 hours after rain, and, after a drought of about 6 weeks. The sampling was done by four people four times during 24 hours, later five times during 30 hours, at midday, in the evening at 7 p.m., at midnight, between 6 and 7 a.m. in the morning and again at midday. These plants were cut with sickles and immediately thrown into alcohol to kill enzymes. Leaves, stems, flowers and fruits were separated when the plants were dead. In the case of Tribulus, roots were taken as well, as sheep pull these out and eat them. A determination of the water content of the leaves was done for every sample.

As wilting is a progressive process in a living plant, no particular experiment could be repeated, but a sufficient number were done to allow of definite conclusions.

Since samples could vary because of assimilation, respiration and migration, some samples of both cut fresh and wilted lucerne were taken during 30 hours. They were kept in basins with or without water (if wilted) exposed to the sun. This was done to eliminate migration. Samples of the cut plants and of the whole plants in the plots were taken in daytime every two or three hours. During night three samples were taken. A number of experiments to ascertain the respiration of cut plants and plants in pots of lucerne and Karoo bushes were carried out. The plants were allowed to assimilate between the tests. The cut plants lived from four to six days before they wilted beyond recovery, the plants in pots lived for one to two months. Actually the latter did not wilt beyond recovery, but were finally cut to determine their dry matter. Every few days their respiration was tested and the moisture content of the soil was measured. In the first few weeks the temperature varied very little as the experiments were done on the south side of a verandah. Later the temperature decreased and a correction for temperature was necessary. As a special paper will deal with these experiments, no further details need to be given here, and only the result whether wilting increases respiration or not is important.

For the chemical analyses, the same methods were used as previously, thus only outlines will be given here. The starch determination was done after freeing the solution with watery alcohol and ether from the sugars, treating with diastase at

suitable temperatures until all starch had disappeared, heating under reflux cooler with hydrochloric acid, clearing and titrating with Bertrand's solution. For the sucrose the material was extracted with 50 per cent. alcohol containing calcium carbonate, boiled and made up to a definite volume. A definite portion was taken out and boiled down to evaporate the alcohol and then taken up with water. 10 cc. invertase solution made from fresh baker's yeast was added, the solution incubated for two hours at 38°C., then filtered and titrated according to Bertrand. For the monosaccharides the process was the same as with sucrose, up to the boiling down of the solution. Then it was made up to a definite volume and the solution treated with washed anchor yeast which precipitates reducing substances other than sugars. The filtrate was titrated according to van der Plank's iodimetric method for glucose and fructose. The value for the reducing sugars has to be deducted from the value for sucrose (invert-sugar).

Discussion of Results.

From the outset it was obvious that none of the investigated plants contained much glucose. Fructose and sucrose, however, were found in normal plants in fair quantity depending on the species. Starch was also found in all the species, very little in the Gramineae and large amounts in Tribulus.

J. M. and M. G. Vassiliew, 1936, and Iljin, 1930 gave some indication of the direction in which changes could be expected, Iljin, as early as 1923, recorded the disappearance of starch during the loss of water but only in single determinations of cut leaves, not in progressive trials on a living uncut plant. The Vassiliews did long term experiments on wheat plants in pots. Their general sample showed that after the disappearance of starch the sucrose content increased, but not for long. Then the sucrose content decreased, while the monosaccharides increased and remained high for some time. Afterwards, the monosaccharides also decreased and the plant died.

There are several complications in the present investigation, viz.—(a) Night and day samples do not give the same result. Even in the three day-time values neither starch nor sucrose content is constant, only the glucose content in normal plants is nearly constant. In later experiments a further day-sample was taken, and in normal plants its values generally agreed very well with those of the sample taken 24 hours earlier. In wilted plants or with changeable weather this was not the case. This is due to the fact that wilting is not a stable process, but progressive. (b) Another complication has a physiological basis. All parts of a plant do not wilt at the same moment. The leaves may be wilted and loose their capacity to form an abundance of starch, but the stems do not wilt to the same extent. It seems that when the leaves of lucerne and Tribulus are wilted, the stems which are not yet wilted, take up the rôle of assimilating organs, and may produce a large amount of starch.

It is only when the plants have wilted beyond recovery that the stems cease assimilation. (c) A third complication is due to transferred assimilation. It might be expected that the photosynthetic activity of the plants would cease when wilting occurs. That is what Iljin reported (1923). But this does not happen in the case of the stems of the plants under investigation. If the stem constituted only a small portion of the whole plant, its photosynthetic activity would presumably have been negligible. In lucerne and Tribulus, however, the stem forms a large part of the plant. Special experiments have been carried out with lucerne to ascertain the ratio of the weight of stems leaves and fruits, and, in Tribulus of the root also. (d) Lucerne and Tribulus were analysed when in flower or fruit, and while carbohydrates were being conducted towards these organs. It appeared that during wilting the carbohydrate metabolism in these organs was more active. In lucerne the flowers constitute only a small portion of the plant, but in Tribulus the fruits form a fair portion of the weight of the whole plant.

These were the complications which presented themselves in the course of this investigation and which have to be taken into consideration in the interpretation of the following results. From these experiments, migration could not be excluded. In the few experiments which were done by cutting the lucerne, the conditions were not exactly the same as in the uncut plant. Increased sugar content by its sheer percentage may lead to starch formation, unless the enzyme is damaged. This may be the case in the wilted, but not in the fresh plant. Thus the results of these experiments will only give a possible indication of what happens with prohibited migration, but not an accurate quantitative representation of what happens in the uncut plant.

Before studying the changes in the wilted plants, it is necessary to know the carbohydrate content of the normal plants. Data were collected since 1941, whole 24-hour curves, since 1942. A few typical examples are as follows:—

Experiments carried out on Hunters River lucerne (11-12 10. 43) and on Tribulus 21-22. 12. 43) (see graphs 1-2 and 4-4c), show that Hunters River had its starch maximum in leaves at 7 p.m., and the sugar maxima were in day time. The sugars did not show much variation by comparison with the starch. In the stem the starch maximum was much lower and occurred at 12 noon, the sugar maxima are in the night. The "Provence" lucerne had a very similar curve, though the starch maximum may be reached earlier in the day. The values were about the same in both varieties of lucerne: starch maximum 6·8 per cent., total sugars in leaves not over 2 per cent, reducing sugar not over 1·3 per cent. Under favourable climatic conditions that seems to be a typical curve for the carbohydrates in lucerne. It could be the curve of any good fodder plant. The stem contained considerably less starch, but more sugars than the leaves. It did not show a very pronounced starch maximum

in the evening. It is noteworthy that the starch did not disappear in any of the organs during the night. It decreased, not so much in the early part of the night, as after midnight.

The carbohydrate curve for the leaves of temporarily wilted or permanently wilted plants (Graphs 3, 3a), was very different. Even in cases of temporary wilting, less starch was formed, more sugars were present, especially more cane sugar. The accumulation of cane sugar, however, did not last for long, at most for about 48 hours. During this time, if the wilting progressed, the starch decreased still more. Only monosaccharides appeared in a rather large quantity. This state apparently lasted for a couple of days. Then the reducing sugars also disappeared. The stems, however, did not wilt as quickly as the leaves and during the first stages of temporary wilting, more starch than usual was found in them. If wilting progressed the starch also decreased, but compared with the leaves the stems are always a step behind. It is interesting to note that even during wilting the starch in lucerne did not disappear entirely, and although it fell as low as 0·4 per cent. there was still a maximum early in the morning (about 1·4 per cent.). This maximum is easily explained. During the night the water content in wilted plants increases as in the early morning even on dry days the moisture in the air is higher rising to 30-40 per cent. as against 20 per cent. in the middle of the day. Later in the day no new starch was built up and that present was slowly converted. That means that in spite of heavy wilting the plant is not yet dead and a reduced metabolism is still going on. Similarly it was found in the respiration experiments, that dissimilation went on for a long time after wilting had set in. It must be fully understood that the investigated lucerne was still fully alive, not dry. The curves for wilted "Provence" lucerne are very similar. The starch maximum, however, may occur somewhat earlier after midnight, quite independently of light, as at that time the moisture conditions are more favourable. With fresh "Provence" lucerne, the starch maximum also occurs earlier than with fresh "Hunters River." The fact that a starch maximum may occur independently of photosynthetic activity gives food for thought, yet chemically and physiologically it is entirely possible.

A number of data and a carbohydrate curve of lucerne badly damaged by insects and subsequently wilted, are of particular interest. At first the plot gave normal starch and sugar values, and was supposed to be used for a grazing experiment, then a caterpillar invasion took place. Within two days the plants wilted; the starch sank to a low level, large quantities of sucrose appeared, but the reducing sugars were still normal. The following day the starch decreased, the sucrose had sunk to normal level, and the reducing sugars had increased. The stems which were much less damaged than the leaves showed a high starch maximum in the evening, strangely enough most of the starch

disappeared during the night. The next day the caterpillars had disappeared and the plants looked somewhat better and less wilted. Immediately the starch content of the leaves increased without, however, reaching its usual magnitude. It may be mentioned that lucerne wilts temporarily by the loss of a few per cent. water. When fresh it has a water content of over 75 per cent., permanent wilting may occur at 65 per cent., temporary wilting at 70 per cent.

The analyses of trampled lucerne are also interesting. Small plots of lucerne, cut and allowed to grow 4 inches to 1 foot were grazed and heavily trampled by two sheep. During the trampling, material was cut in the morning, time being allowed for good assimilation. Very little starch and sugar was present.

The water conditions are very different for *Pentzia incana*, In general, there is nothing new in the daily curve except a fairly high sucrose content; the twigs are nearly the same as the leaves. The starch content is much lower than for lucerne.

Algerian oats even in fresh condition had a very low starch content. In fresh condition, the haulm seemed to form more starch than the leaves, showing a more typical maximum curve. The sucrose was again rather high but very little glucose was present. The amount of the reducing sugars scarcely changed in the 24 hours. In wilted state, the sucrose was very high, but the starch was scarcely affected.

Tribulus terrestris is probably the plant which offers most surprises even in fresh state (Graph 4-4c). It was known that sheep on the Veld Reserve, Fauresmith, throve on this plant and put on weight when they had nothing else to eat. The carbohydrate content varied with changing meteorological conditions. The peak was reached when an experiment was made on a beautiful clear day 24 hours after heavy rains. The leaves contained over 80 per cent. of water.

In the curve for the leaves, the maximum of starch, 5½ per cent., is found at night, not in the evening. During the first day the stems already contained more starch than the leaves and also a fair amount of sugar. Whilst a fair amount of starch disappeared from the leaves after midnight, it increased in the stems from a relative minimum in the evening to the astounding figureof 11½ per cent. by 7 a.m.; by 12 noon, however, it was on the same level as during the previous day. The reducing sugar content in the stem was fairly high in day-time and low in the night. The sucrose content was just the reverse. What happened to the starch and sugars? The fruits accumulated starch and sucrose at night in large amounts, 7 and 4·7 per cent. respectively. But in day-time reducing sugar predominated in the fruits. By the early morning of the second day, a large amount of starch was deposited in the roots. It seems to have migrated as sucrose, as a sucrose maximum was observed six hours before the starch maximum. The starch content of the roots as well as the sugar content was higher on the second day than on the

first day. It must be emphasised that these were the highest starch values ever encountered. But sucrose seems to be always high in fresh Tribulus. In wilted Tribulus, the starch sank as low as ½ per cent. in day-time, and total sugars were not over 1½ per cent. in the leaves. The stems wilt less easily and take over the assimilation and condensation. In temporary wilted Tribulus large amounts of cane sugar especially in stems and roots take the place of the starch. In permanently wilted plants the sucrose disappeared from stem, fruit, leaves and roots; reducing sugars, however, were still present. Smaller amounts of starch were still present in leaves and fruit without, however a pronounced maximum. Stem and root during permanent wilt lost about 60 per cent. of the starch. The stem kept nearly at the same level for 24 hours. The root, however, lost considerable amounts of starch. Temporary wilt in Tribulus occurs between a content of 57 to 67 per cent. of water. The plant recovers again in the night and may contain 80 per cent. of water, whilst permanent wilting occurs between a water content of 45 and 55 per cent.

SUMMARY.

1. Daily variations in the starch, sucrose and reducing sugar content in normal and wilted plants of two varieties of lucerne, Tribulus terrestris, Algerian oats, Panicum minus var. planifolium and Pentzia incana forma were investigated.

2. In all investigated plants starch disappeared during wilting.

3. The wilting of the leaves occurred earlier than that of the stem. In Tribulus, lucerne and Algerian oats, the stem acted as an assimilation organ, accumulating starch.

4. Sucrose was the first sugar to increase after wilting set in. It increased for about two days, then fell below its normal level after which reducing sugars increased somewhat. Starch was always present, although often only in very small quantities.

5. Starch never disappeared entirely at night in experiments done during the growing season from September to May, in the climate of the Orange Free State.

6. The amount of sucrose and reducing sugars found after wilting did not correspond to the amount of starch which disappeared. That may be due to the continued respiration. In cut branches and twigs of Karoo bush and lucerne, a strong respiration continued after heavy water loss or wilting. It decreased later, to increase once more before death. With intact plants of *lucerne* and *Pentzia* there was no evidence that the respiration increased with decreasing water content. The specimens, however, were not allowed to wilt beyond recovery, and there is much scope for further research. Iljin's results of increased respiration in cut wilted plants could not be confirmed for growing plants.

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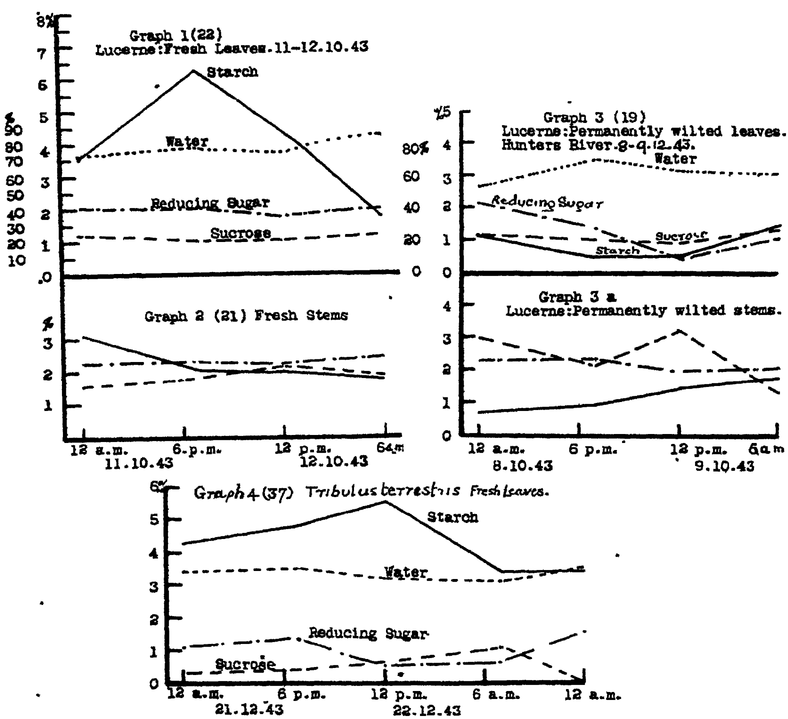
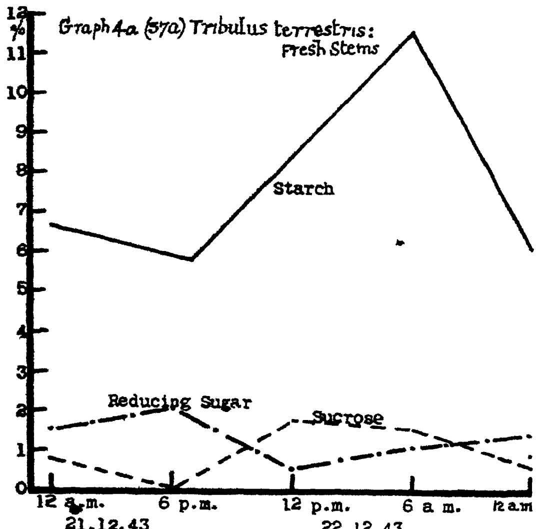
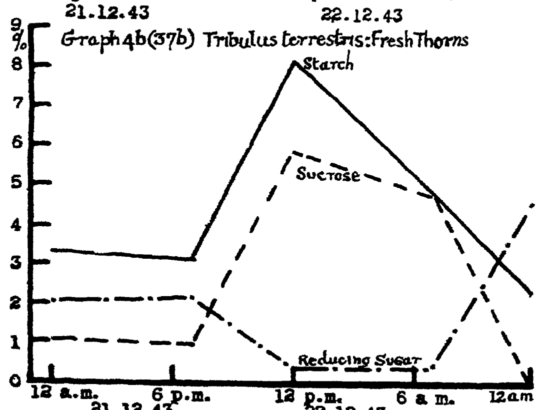
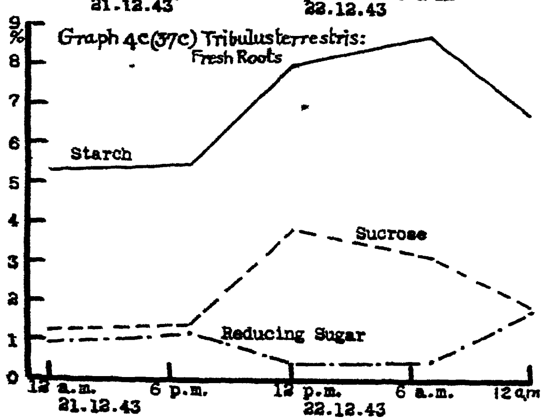



Graph 4a (37a) Tribulus terrestris: Fresh Stems
Starch
Reducing Sugar
Sucrose
12
%
11
10
9
8
7
6
5
4
3
2
1
0
12 a.m.
6 p.m.
12 p.m.
6 a.m.
12 a.m
21.12.43
22.12.43


Graph 4b (37b) Tribulus terrestris: Fresh Thorns
Starch
Sucrose
Reducing Sugar
9
%
8
7
6
5
4
3
2
1
0
12 a.m.
6 p.m.
12 p.m.
6 a.m.
12am
21.12.43
22.12.43


Graph 4c (37c) Tribulus terrestris: Fresh Roots
Starch
Sucrose
Reducing Sugar
9
%
8
7
6
5
4
3
2
1
0
12 a.m.
6 p.m.
12 p.m.
6 a.m.
12 a.m
21.12.43
22.12.43

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DIGESTION EXPERIMENTS WITH FRESH KAROO PLANTS

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Read 3rd July, 1944.

In 1938 Botha published data on digestion experiments with Karoo bushes. It was the first work of this kind on Karoo bushes, and it showed that the digestibility of Karoo bushes differed considerably from the digestibility of grasses. It was found that the richer Karoo bushes, including species of *Salsola*, *Atriplex* and *Tetragonia* could not be fed alone, but had to be mixed with grass of low feeding value. Botha at first mixed Rooigrass (*Themeda triandra*), grown in the surroundings of the Veld Reserve at Fauresmith; yet it, too, appeared too rich, and it was better from the point of view of digestion experiments with Karoo bushes to use poorer hay for the mixture. Thus in all following experiments when the Karoo plants were too rich to be fed alone, dry veld hay from Ficksburg was used, generally in the proportion of two parts of hay to one part of Karoo bush. The sheep liked the hay and several tests had been made to ascertain its digestion coefficient.

The main difference between the digestion of Karoo bushes and grass seems to be that Karoo bush though often much poorer in protein than grasses, had a higher digestion coefficient for protein. Fibre, however, present in a much smaller percentage in Karoo bush leaves, was very poorly digested when dry. The leaves of Karoo bushes were always separated from the woody branches and only the former fed in the digestion experiments. In spite of this the fibre of dried leaves and especially the fibre of the richer plants was very poorly digested.

In view of these results it was thought advisable to use fresh plants, as it was likely that the fibre became indigestible during drying. By feeding fresh plants the work was considerably increased, since material had to be cut and prepared twice to three times a day for three weeks and the water content to be determined at each cutting. A number of plants which were scarcely eaten when dried were eagerly eaten and well digested when fresh. Thus in recent years most experiments have been carried out with fresh Karoo bushes, mixed if necessary with dried veld hay.

I have to thank Mr. L. C. C. Liebenberg, Mr. R. Story and particularly Mr. L. P. Meyer for doing practical work in these experiments.

The following plants were investigated:—*Tripteris pachypteris, Pentzia incana, Phymaspermum parvifolium, Sutherlandia microphylla, Walafrida geniculata, Salsola glabrescens, Atriplex Capensis, Lotononis divaricata, Olea verrucosa, Rhus lancea, Themeda triandra.*

It will be seen that a number of plants tested by Botha were used again and several of which the sheep did not eat in his digestion trials. Except for feeding fresh material the technique used in these experiments is exactly the same as in Botha's trials. The feeding stall and dung bag recommended by the Agricultural Institute at Pretoria were used for the hamels. Thus the present results and Botha's can easily be compared.

First the coefficients for plants which can be fed alone will be compared: *Pentzia incana* and *Phymaspermum parvifolium*. The digestion coefficient of total organic matter is about 10 per cent higher for fresh material, but the coefficient for protein is scarcely altered. The change is due to the much higher digestion coefficient of the fibre and to the higher coefficient for ether extracts. The fibre was 3 to 4 times better digested (*Pentzia* 24·6—58·4; *Phymaspermum* 13—39·7). If *Themeda triandra* was fed fresh there was not the same marked difference as compared with dry material, in fact, the protein and ether extractives were better digested in the hay. In composition the grass was about the same except that it had about 1 per cent. less protein and ether extract, collected at the same time of the year, one in 1937, the other in 1943. The *Themeda* cut in the rainy season of 1943 was exceedingly well digested, much better than the fortnightly-cut *Themeda* of Botha, but it was not possible to repeat the experiment because of the lack of similar grass. All further coefficients agreed with Botha's.

When some years ago the question of plant briquets was discussed in South Africa, trials with powdered *Pentzia* and *Phymaspermum* were made at Fauresmith. The sheep ate this powder, but according to the digestion experiments it was not as good as fresh food, unlike the results in Europe where the briquets were equal to fresh food. As mentioned before, some Karoo plants were not eaten when dried, e.g., species of *Salsola, Helichrysum pentzioides, Lotononis sp.* and *Artiplex capensis*. In the fresh state these plants are eagerly eaten, *Salsola glabrescens* has a high digestion coefficient, especially when its richness in protein is taken into consideration. It is obvious that the sheep thrive well on such veld. But it is equally obvious that it is no use to conserve this food dry, as the plant is then scarcely digested. In no circumstances could species of *Salsola* be fed alone. In the experiment two parts of fresh *Themeda* was given to one part of

Salsola, but the *Salsola* had a higher dry weight. With *Atriplex capensis* the high ash content did not prevent excellent digestion. In one experiment in which *Atriplex* was fed with our best *Themeda* the sheep increased in weight (5-10 pounds) during the experiment and were in prime condition. It was, however, puzzling that the *Themeda* was also much better digested than in any other experiment. From the tests it seems that *Atriplex* was best digested when it had a high protein content regardless of the ash content and there was a good source of other carbohydrates and fibre. Further experiments with *Atriplex* are necessary. Vaalbrak was the plant which gave the highest carrying capacity for sheep in the long run.

Of special interest are the figures for *Walafrida geniculata*, a plant which has become conspicuous in the broken veld and the Karoo. It is very well eaten and digested. *Lotononis sp.*, on the other hand, is very disappointing, the low protein content is still rather poorly digested, equivalent to *Phymaspermum sp.*, *Sutherlandia sp.*, which was fed with grass, had its protein very well digested; the digestion of its ether extract, however, was very variable. Its fibre content, though low, is scarcely digested.

Of the fodder trees *Olea sp.* and *Rhus lancea* were tested. It has been thought that the trees were rather richer in protein and poorer in vital minerals than the small bushes. *Olea* was used at the end of the season and had a poor protein content. It appeared that its protein was not well digested, but the N-free extractives were well digested.

Rhus lancea, fed with hay, gave a good protein digestion, but its fibre was not digested, and, further, the digestibility of the hay fibre which was usually good, over 70 per cent., was reduced by about half. The N-free extractives, however, were well digested. The result was unexpected, but is a good warning of what to expect in times of drought, when these trees are eaten.

In these experiments the period at which plants are grazed has been taken into consideration. The brak soil plants and the trees are grazed in winter and early spring, and in times of drought, and such plants were therefore tested at these times. The plants were probably not at their most palatable stage and the trees were not in their growing period.

Reviewing the results, it may be said that Karoo bushes in the fresh state tested for their digestibility compare very well with grass. Their protein is generally better digested, their fibre less well. Yet the results for fibre are not as disappointing as with dried Karoo bushes. As many dry Karoo bushes (sundried) were not eaten or digested at all, there is no advantage in storing Karoo bush in the form of hay or briquets, as would be the case with grass. The large Karroo bushes seem to be more a source of energy than of protein.

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TABLE I.

Digestion coefficients of fresh Karoo Bushes.

Plant.	Total dry matter.	Total org. matter.	Crude protein.	Ether extract.	Fibre.	N-free extract.
Tripteris pachypteris ...	—	51·5	66·8	11·8	16·1	77·1
Pentzia incana	—	67·3	75·0	74·1	58·4	72·5
Phymaspermum parvifolium	—	47·9	56·1	55·5	39·7	57·8
Lotononis divaricata ...	45·4	48·1	47·1	50·6	42·2	54·5
Walafrida geniculata ...	63·3	67·3	55·6	57·4	55·8	76·8
Salsola glabrescens ...	—	70·5	69·8	97·5	67·6	78·4
Atriplex-capensis ...	—	76·2	80·1	33·0	—	—
with hay, dry, prop. 2 : 1	50·66 anal. IV	42·4	72·7	33·0	—	47·7
with hay, dry, prop. 1 : 1	65·75 anal. III	59·8	75·7	27·4	49·8	66·3
with hay, dry, prop. 2 : 1	68·6 anal. I	68·1	88·3	59·6	56·8	70·3
Very young *Vaalbrak* with excellent Themeda	— anal. II	76·2	79·1	92·5	92·8	—
Olea africana	—	67·4	33·7	57·4	35·6	85·0
Rhus lancea	—	49·44	36·3	82·5	0	70·85
Sutherlandia microphylla	—	51·5	84·3	53·9	0–8	74·3
Themeda triandra ...	fresh Oct. 1943.	56·9	45·6	38·6	59·5	57·3
	dried Oct. 1937.	57·2	51·8	50·3	59·2	56·9

TABLE 2.

Composition of the plants in per cent. of dry matter.

Plant.	Protein.	Ether extract	Fibre.	N-free extractives.	Ash.
Pentzia incana	7·91	3·82	38·02	41·67	8·58
Phymaspermum parvifolium ...	8·33–9·57	4·95	37·16–39·14	40·9–41·03	6·68–7·43
Tripteris pachypteris ...	8·27	3·63	33·84	45·22	9·05
Lototonis divaricata ...	7·10	2·13	50·91	35·37	4·56
Walafrida geniculata ...	8·7–10·15	2·11–4·62	29·94–33·94	46·6–50·4	5 2–10·10
Sutherlandia microphylla ...	22·12–26·07	5 24–4·67	19·10–22·08	43·04–42·30	7·52–7 86
Salsola glabrescens ...	16·47	2·08	25·16	43·02	13·27
Atriplex capensis I ...	12·34	2·00	31·75	40·30	13·61
II ...	20·6	2·68	14·34	35·47	26·91
III ...	14·35	2·01	30·46	35·43	17·75
IV ...	13·4–14·0	3·19	20·4–21·7	39·6–42·6	20·9–22·1
Olea africana ...	6·25	8·32	22·56	56·28	6·59
Rhus lancea ...	12·73	7·29	22·26	50·45	6·25
Themeda triandra T Nov 42	2·21	2·04	32·76	48·97	14·02
,, F Oct 43	5·59	2·13	32·22	46·31	12·96
,, E Apl 43	4·8–5·3	2·32–2·84	31·96–33·16	44·99–46·97	13·12–14·76

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XLI, pp. 218-224, February, 1945.*

EFFECT OF VELD BURNING ON THE BASE EXCHANGE CAPACITY OF A SOIL

BY

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With 1 Text Figure.

Read 3rd July, 1944.

The desirability or otherwise of burning the veld under South African conditions has been studied by many workers and from many points of view, the aspect of greatest practical interest at present being the correlation between soil erosion and the frequency and seasonal incidence of burning, since it is generally accepted that burning under properly controlled conditions is a necessary part of South African veld management. In these circumstances it seemed desirable to enquire whether veld burning has had any effect upon the base exchange capacities of the soils. At first sight such an effect would be expected, for it is obvious that if the soil is itself 'burnt' along with the vegetation, the complex of soil colloids is partly decomposed, and the base exchange capacity thereby decreased. But closer consideration indicated that the effect, if any, would be small, for the depth to which the fire affects the soil temperature is small. Cook (1939) found that while the temperature at the foot of a grass tussock rose for a short time to 600°C. when the fire passed, there is little rise in temperature at a depth of 0·2 inches below the surface; and Prof. Bush, of the Department of Zoology at the Natal University College, pointed out to the writer that most of the microfauna inhabiting the top inch of soil survive the burning.

Schofield's method for obtaining the buffer curve of a soil has been used as a simple and rapid method for investigating any changes that may occur in a soil that has been exposed to a high temperature. By this method results are obtainable for the (positive or negative) amount of base taken up by a soil in order to attain equilibrium with each of six buffer solutions with pH values 1·4, 2·9, 4·6, 7·1, 9·8 and 12·4, respectively. When the results are expressed as milligram equivalents per 100 grams of soil (MGE per cent.), independent replicate experiments usually agree to within about 1 unit, although considerably closer agreement can be obtained with simultaneous replicates (using the same standard solutions).

Before examining the effects of field treatment, some observations were made upon a few soils which were heated to known temperatures under laboratory conditions. The general nature of the results is indicated by the curves in Fig. 1 which shows the buffer curves for a soil from the Natal University College grounds. The general form of these curves is typical of that obtained for many Natal soils: the buffering is poor at the acid end of the range and shows a tendency to increase with increasing pH value. In some cases (including that of the soil to which Fig. 1 refers), there is evidence of a point of inflexion in the region of pH 4·5, but this does not occur with lighter soils. From these curves it is at once apparent that the effects of heating are small, for the control curve and the curves given by the soil after heating to 62°C., 110°C. and 210°C. are roughly parallel and there appears to be no significant reduction in buffering capacity. At higher temperatures there is, however, a moderate decrease in buffering capacity and this occurs mainly in the range up to pH 9·8; the reduction in the already low buffering capacity in the acid range up to pH 4·6, and the smoothing out of the point of inflexion are particularly noteworthy. It has been pointed out elsewhere (Coutts, 1932), on the basis of observations of loss in weight of soil samples heated in a furnace, that organic colloids in soils of the type at present under examination are destroyed in the temperature range 100°C. to 250°C., and inorganic colloids between 250°C. and 450°C.* Since the amounts of organic matter in the soils used in the present experiment are small, this earlier finding appears to provide a reasonable explanation of the negligible alterations in buffering capacity obtained by heating to temperatures below 250°C. The relative stability of the exchange complex in Natal soils had already been noted by Schofield in some unpublished work in which he subjected the soils to various treatments in the laboratory.

By interpolation on curves such as those shown in Fig. 1 the pH values with which the soils are in equilibrium (i.e., the pH value where the curve cuts the axis MGE per cent.=0) can be found, and these 'equilibrium pH values' are given in Table I for two soils, the Natal University College soil and a more sandy wattle soil (Soil K). It will be seen that for the samples heated to 210°C. or less, the variations in these equilibrium values are fairly small and show no definite trend, but that for the higher temperatures there is a significant increase in the equilibrium pH value—a result which is in accordance with the observations of Cook (*l.c.*), who reported a definite rise in alkalinity of the surface soil (to a depth of 1½ inches) on a plot burnt annually. Cook also found a much smaller effect upon a plot burnt in alternate years.

* The actual temperature ranges would, of course, vary for different soil types. Mukherjee, Mitra and Mitra (1943) suggest that variations in the form of the dehydration curves could serve as an indication of the nature of the characteristic minerals in the clay.

The writer is indebted to Messrs. J. A. Pentz and J. D. Scott, of the Estcourt Veld Reclamation Experimental Station for providing him with soil samples from the plots on the veld burning experiment at that station. The samples considered below are described as follows:—

No. 1—complete control; no burning, no grazing, no mowing.

No. 4 and No. 7—Burning is carried out on these plots in February or March in alternate years; No. 4 was burnt in 1938, 1940 and 1942 and No. 7 in 1939, 1941 and 1943. None of these plots was grazed or mown.

Surface samples from No. 4 and No. 7 were taken immediately before burning and again immediately afterwards from as nearly as possible the same parts of the plots; samples designated below as 4/1 B and 4/1 A, 7/2 B and 7/2 A, etc., may be regarded as strictly comparable pairs of samples taken before and after burning respectively.

The ideal method of comparison would be between the control plot and the burnt plots, but this proved to be impracticable on account of the heterogeneity of the soil which is demonstrated by the results quoted in Table II for samples from different parts of the control plot. The sample 1/3 clearly represents a portion of the plot upon which the soil differs significantly from the remainder and in the field it is possible to distinguish soil differences on the plot, but even for the samples that resemble each other most closely (samples 1/1, 1/2 and 1/7), the agreement is hardly close enough to detect with confidence differences of the order of 1 MGE per cent. and, further, it will be seen (from Table III below) that the results on these samples on the control plot differ widely from those for the soils under treatments 4 and 7. The best available procedure, therefore, appears to be to make comparisons between the pairs of samples referred to as A and B in the preceding paragraph.

The results are shown in Table III and are the means of two independent pairs of simultaneous duplicate readings. The range of values of base exchange capacities in the soil under treatment No. 4 is two or three times as great as that found in the soils under treatment No. 7, but the effect produced by burning is of similar type in all cases and is in the same direction, but is smaller in amount than that recorded in Cook's results. An examination of the data in Table III shows that while the alterations in the base exchange capacities in the alkaline region are erratic, there is a consistent tendency in the acid range, represented by a nearly parallel shift of these parts of the curves in such a direction that the equilibrium pH after burning is about 0·2 pH units higher than it was before burning. It is found, also, that the burning did not have the effect observed in the high temperature laboratory experiments of eliminating the inflexions in the curves which are very marked in the case of the soils under treatment No. 4. The quantitative

difference between these results and those found by Cook in the alteration of the equilibrium pH value may be ascribed to fiercer burning in the case of her plots, for the persistence of the inflexion point shows that the temperature at the soil surface in these Estcourt samples cannot have approached the temperature of 600°C. which occurred in her experiments. It would be interesting to repeat these experiments on plots upon which wattle brushwood is burnt, since the burning in this case would probably be fiercer than in the case of a grass cover.

Since the plots had been under treatment for several years before the samples used in this experiment were taken and they still show the small effect of an individual burn, it is improbable that any permanent alteration in the soil properties is caused by the burning as carried out on these plots.

Summary.

1. Laboratory experiments show that the base exchange capacity of a soil is scarcely altered by heating the soil temperatures up to about 250°C.; but exposure to temperatures between 250°C. and 500°C. causes a moderate reduction (of the order of 20 per cent.) in buffering capacity.

2. The influence upon base exchange capacity of veld burning under field conditions is very small and probably transitory.

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TABLE I.

Effect of heating a soil (under laboratory conditions) upon its buffering capacity and its equilibrium pH value.

	Temperature.					
	[control]	62°C.	110°C.	210°C.	360°C.	480°C.
N.U.C. Soil.						
Equilibrium pH	4·6	4·9	4·8	4·9	6·6	6·1
Base exchange capacity (pH range 1·4 to 12·4)	46·4	45·1	45·9	45·8	36·6	31·2
Soil K.						
Equilibrium pH	4·4	4·1	3·8	4·3	6·1	6·2
Base exchange capacity (pH range 1·4 to 12·4)	40·2	38·0	35·6	41·7	30·0	31·2

TABLE II.

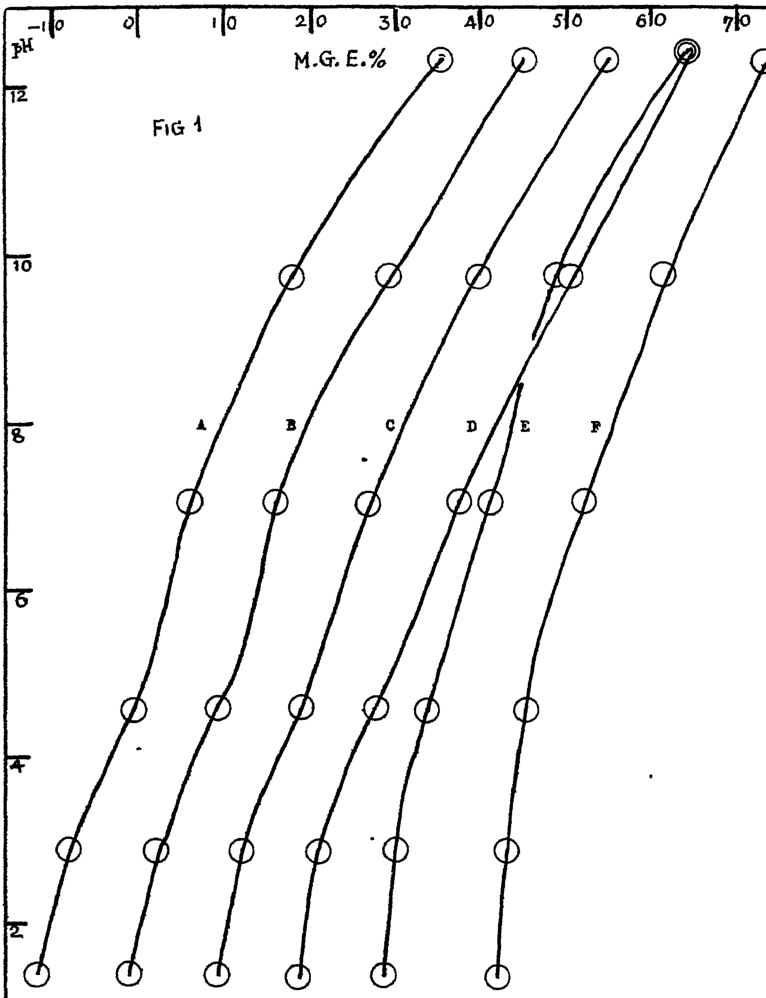
Base exchange capacities for five samples of soil under treatment No. 1 (Estcourt).

pH	1/1	1/2	1/3	1/4	1/7
1·4	– 6·9	– 8·5	–12·5	–10·4	– 7·2
2·9	– 5·1	– 6·0	– 7·9	– 6·6	– 5·0
4·6	– 0·8	– 1·2	– 1·2	– 1·4	– 0·9
7·1	4·8	4·7	5·8	4·6	5·0
9·8	13·6	14·6	18·6	16·0	13·7
12·4	22·6	27·5	35·8	29·8	25·1

TABLE III.

Base exchange capacities for soils under Treatments No. 4 and No. 7 (Estcourt), for comparable samples taken after and before burning (A and B, respectively).

pH	4/2			4/4			7/1		
	A	B	A-B	A	B	A-B	A	B	A-B
1·4	−25·15	−24·69	−0·46	−23·50	−22·41	−1·09	− 6·74	− 6·21	−0·53
2·9	−17·89	−16·93	−0·96	−17·17	−15·59	−1·58	− 4·98	− 4·34	−0·64
4·6	− 4·47	− 3·57	−0·90	− 4·43	− 3·83	−0·60	− 1·48	− 0·98	−0·50
7·1	6·07	6·52	−0·45	7·36	7·68	−0·32	3·87	4·06	−0·19
9·8	26·51	27·00	−0·49	27·68	28·26	−0·58	12·14	12·13	0·01
12·4	60·41	60·40	0·01	61·21	60·30	−0·09	21·83	22·75	−0·92
Eqm. pH	5·6	5·4		5·6	5·4		5·3	5·0	
pH	7/2			7/3			7/4		
	A	B	A-B	A	B	A-B	A	B	A-B
1·4	− 6·85	− 6·73	−0·12	−11·09	−10·55	−0·46	− 8·49	− 8·00	−0·49
2·9	− 5·01	− 4·78	−0·23	− 7·65	− 7·10	−0·55	− 5·75	− 5·22	−0·53
4·6	− 1·25	− 1·07	−0·18	− 1·82	− 1·57	−0·25	− 1·24	− 1·00	−0·24
7·1	4·19	4·02	0·17	5·35	5·58	−0·23	4·73	5·37	−0·64
9·8	12·20	12·09	0·11	18·91	18·88	0·03	15·13	16·04	−0·91
12·4	23·05	21·56	1·49	36·91	35·68	1·23	26·32	27·44	−1·12
Eqm. pH	5·2	5·1		5·2	5·0		5·2	5·0	



INDEX TO DIAGRAM (Fig. 1).

Buffering curves for N.U.C. soil. Curve A, control; curves B C, D, E, F, soil heated to 62°, 110°, 210°, 360° and 480° respectively The abscissa units refer to Curve A; other curves are shifted progres sively 10 units to the right.

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FURTHER STUDIES OF TETRAPLOIDY IN *CARICA PAPAYA, L.*

BY

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With 3 Text Figures.

Read 4th July, 1944.

The present study, which is a continuation of work previously reported on (Hofmeyr and van Elden, 1942), was conducted at the Subtropical Horticultural Research Station, Nelspruit, by kind permission of the Chief, Division of Horticulture, Pretoria.

It was reported in the abovementioned paper that tetraploidy was induced in *C.papaya, L.* by treating the apical buds of young seedlings, before they were transplanted, with either aqueous or agar solutions of colchicine. As the mortality of transplants is, however, frequently high and valuable material may be lost, established plants approximately 12 inches high and with stems half-an-inch in diameter were now treated with agar solutions according to the method previously described (Hofmeyr and van Elden, 1942). That method also suggests a means of treating other plant material in the open.

Colchicine concentrations of 0·06 per cent. to 0·1 per cent. were effective after the apical buds had been subjected to the action of the drug for periods ranging from 8 to 24 hours. Tetraploidy was induced, apparently, in 2 per cent. of the cases. In some instances, however, only a sector became tetraploid so that diploid and tetraploid tissue became intermixed in the later development. Consequently, the fruit on the same tree showed marked differences in shape, ranging from pear-shaped to almost disc-shaped fruit, depending on the degree of predominance of either diploid or tetraploid tissue. Other types of chromosomal aberrations causing pollen sterility and the abortion of pistillate flowers were observed, but have not yet been examined cytologically.

In the previous paper, the characteristic differences between tetraploids and diploids were described. In the present study, most of the facts there reported were confirmed. There are, however, differences with respect to the nature of the triploid seed described and the fertility of tetraploids. The so-called "triploid" seed was germinated and the resultant progeny proved to be diploid. Closer examination showed that the fruit from which the seed had been taken, although resembling a tetraploid in general appearance, was composed of a mixture of diploid and tetraploid tissue.

SEED STUDIES.

Tetraploid seed is nearly twice the size of diploid seed. The average weight of 50 tetraploid seed is 1·272 gms. and of 50 diploid seed, 0·748 gms. The difference in weight is significant at a P value of less than 0·01. It was expected that the triploid seed which resulted from the cross between a diploid pistillate plant and a tetraploid staminate plant, would be intermediate in weight between tetraploid and diploid seed. Actually, 50 such seeds weighed on the average 0·280 gms. which is significantly less than diploid seed (P is less than 0·01).

Both tetraploid and diploid seed showed a high percentage of germination, but, although several hundred triploid seeds were sown, not a single one germinated. Externally the triploid seed seemed to be normal, but cross-sections showed that the seeds were devoid of an endosperm. Although pollination did not result in the development of normal seed, the fact remains that the seed had undergone considerable development, especially when it is compared with the rudimentary " seed " of parthenocarpous fruit (Parthenocarpy may be induced in the papaya by preventing pollination.) The difference was also reflected in the almost normal size of the fruit compared with the diminutive parthenocarpous fruit. It is not known whether fertilisation actually takes place, and should that be the case, whether sterility is caused primarily by the failure of an embryo to form, or, secondarily, by the failure of the endosperm to develop and thereby inhibiting the growth of the embryo beyond the initial stages.

The reciprocal cross (tetraploid x diploid) where the diploid is the staminate parent, was made several times but has not been successful. Up to the present most flowers have dropped shortly after pollination. Some fruits which were open-pollinated and had access to pollen from both diploid and tetraploid sources developed a few seeds most of which were empty. The results of this cross are too meagre to draw any definite conclusions, but they apparently suggest that such a cross might be incompatible.

Fully developed tetraploid fruit has 150-450 seeds and diploid fruit 700-1,200 seeds. This difference in the number of seed is, partly due to the fact that the seed cavity of the tetraploid fruit is smaller than that of the diploid, and partly to sterility. It was shown (Hofmeyr and van Elden, 1942) that a certain amount of sterility occurred in the pollen of tetraploids, this would be expected to occur, in like manner, in the ovules.

PROGENY STUDIES.

According to the hypothesis of sex determination of *C.papaya, L.* developed by the author (Hofmeyr, 1938), M_1 determines maleness, m femaleness and M_2 hermaphroditism, so that the genotypes of staminate, pistillate and hermaphrodite plants would be, respectively, M_1m, mm and M_2m. It was observed that staminate plants (M_1m) occasionally bore fruit but the

M_1M_1 genotype never appeared in their progenies (Hofmeyr, 1941). However, Storey (1941), discovered that the M_1M_1 seeds were sterile and devoid of an endosperm.

The genotypes of the staminate and pistillate tetraploids induced by colchicine should have been respectively, M_1M_1mm and mmmm and these were used in the crosses reported in Table 1. The M_1M_1mm parent produced a few fruits similar to that of the fruit-producing diploid staminate plant (M_1m). Two types of staminate plants occurred in the progeny of the cross, mmmm x M_1M_1mm, e.g.:—A-type (see Fig. 1), which occasionally bears a few cucumber-shaped fruits similar to the male parent and therefore is presumably of the genotype, M_1M_1mm; B-type (see Fig. 2), which differs distinctly from the A-type with respect to the comparatively heavy fruit crop produced, and also with respect to the shape of the fruit which is very similar to that of the female tetraploid (Fig. 3). The staminate plants recorded in the third column of Table 1 could not be classified as A or B types since they were still too immature when the classification was made.

TABLE 1.
Progeny Studies of Tetraploid Crosses.

Cross.	Staminate Plants.				Pistillate Plants.
	B Type.	A Type.	Unclassified.		
mmmm x M_1M_1mm ...	21	12	18	...	21
M_1M_1mm (selfed) ...	—	—	12	...	2

The progeny of the cross mmmm x M_1M_1mm should occur, theoretically, in the ratio of, 1 M_1M_1mm : 2 M_1mmm : 1 mmmm, i.e., three male or male-like plants to one female. According to the results of this cross (Table 1), there were 51 males and 21 females which is a close approximation of the expected 3 : 1 ratio (P=0·30—0·50). Furthermore, it is seen that of the staminate plants which could be classified into A or B type, there were 12 of the former and 21 of the latter, giving a close fit (P=0·70—0·80) to an expected 1 : 2 ratio. This, apparently, lends additional support to the assumption that the genotype of the B type is M_1mmm. The close agreement of the observed results with expectancy indicates that the pairing of the M_1 and m " sex chromosomes " during meiosis, is entirely at random.

Only a relatively small progeny was obtained from the selfed male tetraploid. The theoretical expectancy of the progeny of such a plant would be 15 male or male-like plants to 1 female. It was indicated previously that the M_1M_1 sex type was lethal hence it may be safely assumed that the $M_1M_1M_1M_1$ genotype will not appear in the above progeny. Hence, the expected ratio should be 14 : 1. Actually, 12 plants were found to be

staminate and 2 pistillate which is a fair (P=0·20—0·30) approximation of such a ratio.

Discussion.

It was indicated in a previous paper (Hofmeyr, 1939a), that the pistillate type is the most stable sex form, followed by the staminate type, with the hermaphrodite the least stable. The degree of sex reversal occurring in the flowers of these sex forms as a result of fluctuations in the environment, was taken as an index of sexual stability.

Five types of flowers ranging from pure staminate to pure pistillate flowers are produced on the hermaphrodite, the sequence depending on environmental changes affecting the growth of the plant (Hofmeyr, 1939a). Of the two normal types of hermaphroditic flowers produced, it was indicated (Hofmeyr, 1939a), that the 5-stamen form may be regarded as more female-like than the 10-stamen form. It is interesting to note that the hermaphroditic flowers produced by the M_1mmm genotype are almost entirely of the former type and those of the M_1M_1mm genotype almost entirely of the latter. The comparatively heavy fruit crop of the M_1mmm genotype is a further indication that the sexual balance is pushed in the direction of femaleness. This observation lends additional support to the hypothesis of sex determination, based on the balance of male and female determiners, developed by the author (Hofmeyr, 1939b). It is hoped to obtain an $M_1M_1M_1m$ sex form in the progeny of selfed M_1M_1mm plants so that further information may be obtained with respect to the relation of the genotype and sexual stability.

In the diploid plantings about 5 per cent. of staminate plants are required to ensure adequate pollination and the remainder is usually, weeded out.

On the other hand, the tetraploid staminate plant of the genotype M_1mmm may be utilised both as a source of pollen and for its fruit. In an ordinary papaya planting, 3 or 4 plants must be planted per hill in order that an even stand of fruit-bearing trees may be obtained after the surplus males are removed as soon as the plants can be identified for sex. The utilisation of both staminate and pistillate plants for fruit production in the case of the tetraploid is a distinct advantage over the diploid, and would mean a considerable saving of both labour and plant material.

The quality of the tetraploid fruit is just as good, if not better, than that of the diploid, the fruit is also more compact and has a smaller seed cavity. Although the results so far obtained are promising it is too early to say whether the tetraploid papaya will become of commercial importance. However, they are sufficiently suggestive to warrant further attention

Summary.

Tetraploid seed is nearly twice the size and weight of diploid seed.

The seed of the cross, tetraploid x diploid weighs less than diploid seed. It is sterile and cross-sections show that the endosperm fails to develop.

The limited data of the reciprocal cross suggest that it is incompatible.

Tetraploids are less fertile than diploids which is indicated by comparative seed counts.

The progeny of the tetraploid cross, mmmm x M_1M_1mm, gave a good approximation of an expected 3 : 1 ratio of males to females, which suggests that the pairing of the M_1 and m " sex chromosomes " is at random during meiosis.

Two types of staminate plants, presumably of the genotypes M_1M_1mm and M_1mmm could be clearly identified in the progeny of this cross.

These two types are characterised as follows: M_1M_1mm type occasionally produces a few fruit which develop almost entirely from 10-stamen hermaphroditic flowers; fruits mostly cucumber-shaped. M_1mmm type produces a comparatively heavy fruit crop which develops almost entirely from 5-stamen hermaphroditic flowers; fruit round to almost disc-shaped, similar to the pistillate type.

The M_1mmm genotype is more female-like than the M_1M_1mm genotype as is indicated by the difference in the amount of sex-reversal occurring in their flowers.

Selfed M_1M_1mm plants yield a progeny which gives a close fit to a theoretical expectancy of 14 males to 1 female, if it is assumed that the $M_1M_1M_1M_1$ genotype is lethal.

The quality of the fruit of tetraploids is equal to that of diploids, is more compact and has a smaller seed-cavity.

Since the M_1mmm staminate plants may be utilised both for their fruit and as a source of pollen, tetraploid plantings have a distinct advantage over diploid plantings in this respect.

Additional research is necessary before the tetraploid papaya could be recommended commercially.

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Fig. 3

Fig. 2

Fig.

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DODDERS AND LUCERNE IN SOUTH AFRICA

BY

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Read 4 July, 1944.

Introduction.

Dodder, which is the common name for several species of *Cuscuta* in the family Convolvulaceae, has become increasingly wide-spread in South Africa of recent years, and much concern has been felt by farmers as a result of its invading farm lands and attacking the important crop, Lucerne.

Yuncker (1932 : 113) records 13 species for S.A.; Flora Capensis (Thistleton-Dyer) (1904 : 84) records 8. while Marloth (1932 : 106) records 10. In the present paper 18 species are recorded, of which 11 are indigenous in Africa.

Below is a list of the species found in S.A. and the authorities recording them (species marked with † are indigenous in Africa):—

Authorities: Y — Yuncker (1932 : 113); F.C. — Flora Capensis, Wright in Thistleton-Dyer (1904 : 84); N.H.—National Herbarium; A.H.—Albany Museum Herbarium; B.H.—Bolus Herbarium; F.—Fourcade (1932 : 89) (1941 : 33); M.— Marloth (1932 : 106).

	A.H.	B.H.	F.	F.C.	M.	N.H.	Y.
Cuscuta africana† . .	x	x	x	x	x	x	x
,, *alpestris*† .			x				
,, *angulata*† .	x	x		x	x	x	x
,, *appendiculata*† .	x	x	x	x		x	x
,, *bifurcata*† .						x	x
,, *campestris* .						x	x
,, *cassytoides*† .	x	x	x	x		x	x
,, *chinensis* .	x					x	
,, *cucullata*† .							x
,, *epilinum* . .					x	x	
,, *epithymum* .	x				x	x	
,, *europea* . .					x		
,, *Gerrardii*† .	x	x		x			x
,, *Kilimanjari*†							x
,, *madagascarensis var. Schlecteri* .							x
,, *medicaginis* .	x	x		x	x	x	x
,, *natalensis*† .	x	x		x		x	x
,, *nitida*† . . .	x	x		x	x	x	x

Species of *Cuscuta* have been recorded in the Cape Province, Orange Free State, Transvaal, Natal, Zululand, Namaqualand and Griqualand. At the present time the genus is probably most prevalent in the Cape Province which also has the largest number of species (12). *C. campestris*, a native of the United States of America, is the most widely spread, occurring in the Cape Province, Orange Free State, Transvaal and Natal.

HOSTS IN SOUTH AFRICA.

The hosts of eight species have been investigated in detail and the numbers and types are summarised in Tables I. and II. These were obtained from records in books and herbaria and from observations in the field.

TABLE I.
NUMBER AND TYPE OF HOSTS.

Species.	No. of Hosts. (species)	No. of Families.	No. of Monocotyledons.	Rough % Woody Hosts.
C. Africana ...	15	11	1 (Restionaceae)	60
C. angulata .	12	9	—	66·7
C. appendiculata ..	33	15	1 (Cyperaceae)	42
C. campestris ..	81	29	8 (Gramineae and Cyperaceae)	13·6
C. cassytoides ...	10	7	—	70
C. Chinensis ..	5	4	1 (Cyperaceae)	—
C. epithymum ...	20	14	3 (Gramineae)	—
C. medicaginis ..	3	3	—	—

TABLE II.
NUMBER OF HOSTS OF THREE TYPES.

Species.	Indigenous Hosts.	Cosmopolitan Wild Hosts.	Cultivated Hosts.
C. Africana	15	—	—
C. angulata	11	—	1?
C. appendiculata	31	2	—
C. campestris	41	32	8
C. cassytoides	8	—	2
C. Chinensis	1	2	2
C. epithymum	10	8	2
C. medicaginis	—?	1	2?

The range of hosts of most species is seen to be wide, notably in the case of *C. campestris*. No species shows a definite preference for one particular host or for one particular family. The number of indigenous hosts exceeds that of cultivated or cosmopolitan wild hosts in most cases.

The chief plant of economic importance attacked by dodder is lucerne, though mention must also be made of records of dodder on citrus by Doidge and Bottomly (1931 : 44) and on

grape vine by Naude (N.H. No. 27053). Carrots in the Queenstown district are also said to have been attacked. The following additional plants of economic importance have been given as hosts of dodder in the United States by Hansen (1921 : 3): hemp, parsnip, turnip, raspberry, cucumber, flax and sugar beet.

Dodder on Lucerne.

The following species have been recorded on lucerne in South Africa:—

C. campestris by weed inspectors who reported to the writer its occurrence in many districts of the Cape Province in 1939-42.

C. epithymum by Kretzschmar (N.H. No. 10788) in the O.F.S. in 1914, and by weed inspectors at Calitzdorp, who reported it to the writer in 1939.

C. medicaginis by Potts (N.H. No. 1932) at Middelburg; by Galpin (N.H. No. 1760) at Queenstown; by Rattray (N.H. No. 830) at Johannesburg, and by White (N.H. No. 485) near Grahamstown.

In 1939-42, when this research was being carried out, the writer found only two species on lucerne in the Cape Province. They were *C. campestris* and *C. epithymum*, and from information given by farmers and from personal observation it was found that the dodder occurred on the surrounding vegetation as well as on lucerne, and showed no marked preference for the latter.

The susceptibility of ten varieties of lucerne to dodder was tested at Rhodes University College, and all varieties were found to be attacked with equal vigour.

Effect of Dodder on Lucerne.

Dodder flourishes better in proportion as the hosts are stronger, healthier and more able to supply food without being forced to succumb to the constant drain.

The effect of this parasite on lucerne is purely physiological, no cases of anatomical change having been noticed. It was found that the condition of the lucerne rapidly deteriorates once the infestation becomes severe; its shoots dry out and turn brown, fewer leaves are produced and altogether growth is retarded. In addition the affected plants showed a marked tendency to become attacked by Fungus diseases, the chief one being Pseudopeziza leaf-spot, whereas the plants free from dodder showed very slight signs of disease, if any.

Lucerne is not usually killed by dodder, though in most cases it was found to die down after a while. Then later, when the dodder had dried out, and especially after rain, fresh shoots were produced by the lucerne. These, however, were no sooner flourishing than the dodder too revived, sending forth new shoots from the old dead-looking twines round the lucerne stems.

C. campestris, by its habit of growing chiefly over the top of lucerne, probably harms it also by bearing down on it and almost smothering it.

C. epithymum seems on the whole to have a slightly worse effect than *C. campestris* and this is probably due to its habit of attacking lucerne near the base of the stem, and thus preventing a good deal of the food and water supply from reaching the upper parts of the host.

Propagation of Dodder

I.—*By Seed.*

Most species produce large numbers of small membranous capsules containing about four seeds and with no special mechanism for dehiscence.

Various authors, notably Egginton and Robbins (1918 : 1) who have studied the problem of dodder in the United States, state that the principal source of its first introduction is as impurity in commercial seeds, e.g., of Lucerne. The size of the seed is such that it is not removed in the threshing of lucerne, and so is left, unless some special means of separation is practised.

That the seeds of both *C. campestris* and *C. epithymum* can germinate when covered by water several inches deep, has been shown by the writer; in fact a higher percentage of seeds germinated under these conditions than when placed on damp filterpaper or in sawdust under various temperatures. The seedlings were able to live and grow in the water for about 10 days.

The writer considers that the chief means of spread in South Africa is probably by water. It seems significant that the commonest habitat of dodder in the veld is along river banks. Once it is established there it can be carried downstream and spread further and further from the river bank and may eventually reach farm lands.

Irrigation water in South Africa also plays an important part in the spread of dodder. In the Cape Province dodder has frequently been noticed growing on the vegetation (chiefly weeds) on the banks of irrigation canals before it has reached farm lands Farmers who have eradicated such dodder before it flowered saved their lands from infestation.

The prominent part played by domestic animals, such as cattle and sheep, in the distribution of dodder seeds appears to be taken for granted in all countries where dodder occurs, and by such authorities as Egginton and Robbins (1918 : 1), Hansen (1921 : 3) and Heald (1926 : 813). It is assumed that the seeds are eaten and pass through the animal's alimentary canal unharmed. As the writer found no evidence for this assumption, experiments were undertaken to test it. Dr. Quin kindly assisted by feeding seeds of *C. campestris* to animals at Onderstepoort and dispatching the desiccated manure to the writer. The

number of seeds retrieved (chiefly by hand-sorting) and their germination is summarised below:—

TABLE III.

GERMINATION OF SEEDS RETRIEVED FROM MANURE.

Source.	Approx. No. Seeds Consumed.	No. Seeds Retrieved from Desiccated Manure.	No. Seeds Germinated.	Percentage Germination.
Donkey	4,500	431	1	·23
Goat	4,500	22	3	13·6
Sheep	4,500	8	6	75
Cattle	4,500	6	1	16·6

The fact that a much larger percentage of seeds was retrieved from the donkey manure than from the manure of the other animals may be related to the different modes of feeding. In the feeding of ruminants such as sheep, goats and cattle, a large proportion of seeds is probably crushed during the cud-chewing process.

In addition, animals probably help in the spread of dodder by carrying the seeds on their feet after grazing on lucerne lands.

VIABILITY OF SEEDLINGS.

The length of time a seedling can live without having attached itself to a host by means of haustoria, seems to be governed largely by the degree to which it is protected from the weather, especially influences tending to increase its transpiration.

Seedlings of *C. campestris* and *C. epithymum* grown by the writer in a greenhouse survived for as long as a month without a host, but even under these sheltered conditions the viability of the seedlings was by no means high; only about 50 per cent. became established on host plants when germinated in the vicinity of suitable hosts.

Under natural conditions the writer found that the viability of seedlings was extremely low. The results of infection experiments carried out on lucerne are as follows:—

TABLE IV.

RESULTS OF INFECTION EXPERIMENTS WITH SEEDLINGS ON LUCERNE UNDER NATURAL CONDITIONS.

Species of Dodder.	No. Seedlings Used.	No. Seedlings Established on Lucerne.	% Seedlings Established.
C. campestris	411	19	4·6
C. epithymum	44	0	0

From these experiments it is concluded that only a small percentage of seedlings survive under natural conditions and become established on host plants.

II.—*By Detached Pieces of Stem.*

Both Hansen (1921 : 3) and Heald (1926 : 813) have recorded the fact that fully detached pieces of stem provided with at least one bud but with no connections to a host, can help in the spread of dodder.

This was tested by the writer with detached pieces of *C. campestris* and *C. epithymum*, ranging in length from 3 to 12 inches. Both were found to be capable of independent existence for some days, the length of time depending largely on weather conditions. It was proved that at least 70 per cent. of the cut stems survived and carried on infection when placed amongst lucerne growing in experimental plots. The number which survived depended largely on drying influences tending to increase transpiration before haustorial penetration had actually been accomplished. In most cases the parasite stems were found to form close twines around the host within 24 hours, while haustoria were formed within the next 24 hours. Once the haustoria penetrate a nutritious host the survival of the parasite is generally assured.

Since the epidermis is very thin and delicate, and the stems, if growing on a nutritious host, are extremely turgid, one is led to conclude that in farm lands, stock, humans, and even farm machines brushing past vegetation infected with dodder, cause pieces of stems to become detached, and so spread to other plants.

III.—*Perennation.*

Most species of dodder are said to be annuals, those in cold climates being killed by frost. There are records, however, of certain species being perennial, especially in warm climates. Several species in South Africa are perennial. Marloth (1932 : 106) has recorded the perennation of *C. africana* by means of haustorial tissues embedded in the host stem. So far no other species has been found to perennate in this particular manner in South Africa.

In the U.S.A. where most dodders are annuals, Stewart and French (1909 : 28) have shown that *C. epithymum* is perennial on Alfalfa (*Medicago sativa*), and that the continuation of infestation is more often due to resumption of growth by overwintered stems than to germination of new seed.

Both *C. compestris* and *C. epithymum* may be perennial in South Africa, new shoots being produced from old, shrivelled, close twines of the stem around a host. In this way new infestations may have their origin, the dodder becoming active after a dormant period.

SUMMARY.

1. Eighteen species of Cuscuta are recorded for South Africa, the largest number of species occurring in the Cape Province.

2. The species studied show no marked preference for one particular host, and in most cases the range of hosts is very wide.

3. Only two species, viz. *C. campestris* and *C. epithymum* occur on lucerne in the Cape Province at the present day, and their effect on lucerne is purely physiological.

4. The spread of dodder by seeds is mainly through the agency of water and impure lucerne seed, though grazing animals probably carry seed on their feet and are capable of disseminating viable seeds in their manure.

5. The viability of seedlings under natural conditions is very low.

6. Detached pieces of stem have a high viability and are capable of causing new infestations.

7. *C. campestris* and *C. epithymum* perennate by means of new shoots produced from old closely twined stems round the host.

ACKNOWLEDGEMENTS.

The writer wishes to express her indebtedness to the Government for a Noxious Weed Research Grant and to Mr. E. du Toit, Chief Weed Inspector, Eastern Province area, for his valuable assistance in connection with the collecting of dodder material. Thanks are also due to members of the botany staff, Rhodes University College; to Miss E. E. Archibald for her assistance in the cultivation of experimental lucerne plots, and to Professor N. J. G. Smith for advice.

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South African Journal of Science, *Vol. XLI, pp. 238-242, February, 1945.*

DISTRIBUTION OF MANGROVES IN THE EASTERN CAPE PROVINCE

BY

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With 3 Photos.

Read 3rd July, 1944.

Records of the occurrence of mangroves on the coast of the Eastern Cape Province are scanty. The recognised authority on marine seed drift on the S.A. coast mentions that *Avicennia marina (Forsk) Vierh (A. officinalis)* has been reported from near East London, but that he had not found it there (Muir: pp. 60, 95).

He gives the Kei River mouth as the southernmost locality for *Bruguiera gymnorrhiza Lam.* and for *Rhizophora mucronata Lam.* (Sim: pp. 223-224 and 287) contains nothing materially different.

The National Herbarium, Pretoria; the Natal Herbarium, Durban, and the Albany Museum, Grahamstown, contain no records for *Rhizophora mucronata* south of Isipingo, Natal, and there is consequently some doubt whether the Eastern Cape records for this species are correct.

Bruguiera gymnorrhiza has been collected as far south as Kei Mouth and *Avicennia marina* in the Kentani district just north of the Kei. These are the southernmost collections. Further north both species have been collected at the Xora River mouth, and *Bruguiera gymnorrhiza* is recorded as seen near Port St. Johns by Muir (p. 69).

In 1943 the writer collected both *Avicennia marina* and *Bruguiera gymnorrhiza* at the mouth of the Bashee River.

These are the only localities in the Eastern Cape Province from which mangroves are definitely recorded. There are no records for the 130 mile stretch of coast between Port St. Johns and Isipingo, the southernmost locality in Natal.

In view of the apparent sporadic distribution of these tropical species so far south, special interest is attached to the establishment and development of mangrove communities in the Eastern Cape, and for this reason further details of their occurrence at the Bashee mouth are given.

The Bashee River mouth, which is approximately 36 miles E.S.E. of Idutywa, was visited by the writer at the end of June, 1943. The river forms the boundary between the coastal districts of Elliotdale and Willowvale. It enters the sea about 58 miles S.W. of Port St. Johns and 42 miles N.E. of Kei Mouth. The estuary is wide and is bordered on either side by mud flats, which are fairly extensive at low tide.

On the north bank, in the Elliotdale district, a small colony of *Avicennia marina* and *Bruguiera gymnorrhiza* extends over about an acre of mud flat. This colony is of particular interest because it has been established comparatively recently, and the whole process of development is still very obvious.

The habitat is a salt marsh periodically inundated by the sea at high tide and covered by a *consocies* dominated by a Salicornia sp. (probably *S. natalensis*). This early stage in the halosere is being invaded by the mangroves, of which *Avicennia marina* is at present the most important species, and is represented by the greater number of individuals, which vary in age and size from a tree 20ft. high to recently established seedlings, and together constitute a family founded by simple aggregation, i.e. by the grouping of gemmules about the parent plant.

These individuals may be grouped into approximately six classes as follows:—

1. The parent tree is about 20 feet tall. It is a rounded, shrubby tree with low, hanging, spreading branches, and is densely encircled with pneumatophores which extend to a distance of 42 feet from the base of the bole. The pneumatophores are particularly dense within a radius of 18 feet. The mud under and around this tree was densely littered with fruits, many of which were already rooted.

2. The next largest tree is approximately 18 feet tall. It is considerably smaller in spread than No. 1, from which it is about 20 feet distant. The development of pneumatophores and the amount of fruit on the mud beneath this tree were both considerably less than in the case of No. 1.

3. There are approximately 10 small trees up to 10 feet tall. These small trees show a single unbranched main stem and exhibit pneumatophores to a distance of 5 feet from the bole. All were in flower, and under some a few ripe fruits were found lying on the mud.

4. Seedlings 3 feet to 5 feet tall, exhibiting pneumatophores from 1 foot to 3 feet from their boles, were numerous. They showed neither flowers nor fruits.

Two dead plants belonging to this class were observed. They had died very recently, because their leaves were still attached to their branches. The cause of death was not apparent.

5. Even more numerous were seedlings which varied in height from 1 foot to 2 feet 6 inches. The great majority of these showed no pneumatophores.

6. Under and around the large trees the mud was littered with large numbers of growing fruits.

From an inspection of the colony it would appear that Classes 6, 5, 4 and 3 represent successive annual generations. This means that the young trees belonging to Class 3 are probably between 3 and 4 years old. The two larger trees of Classes 2 and 1 are considerably older. It appears probable that the Class 2 tree is the sole surviving member of an early crop of fruit from the (Class 1) parent tree, but it is equally possible that it resulted from a second invasion of the same area.

The great difference in size between the Class 2 tree and the small trees of Class 3 suggests that there was a considerable gap between the establishment of these two classes.

The rapid increase observable in the numbers of members of the decreasing age groups is striking. This is largely due to the increase in size of the annual fruit crops produced by the trees of Classes 1 and 2 as they approach maturity; an increase in the size of the fruit crop, implying a corresponding increase in the chances of seedling survival.

Fairly recently the *A. marina* family has been invaded by *Bruguiera gymnorrhiza*. Young *B. gymnorrhiza*, varying in height from 2 feet to 4 feet, are now scattered throughout the area. Practically all of these small specimens were bearing fruit.

The colony made up of these two species of mangrove is still a very open community, but it will be interesting to note which species eventually assumes dominance as aggregation and ecesis proceed.

No other mangroves were seen on the north bank of the Bashee, but on the south bank, in the Willowvale district, there is a dense and apparently pure stand of *Bruguiera gymnorrhiza* consisting of several hundred trees up to about 10 feet in height. Unfortunately, my visit was a hurried one, and it was not possible to examine this community at close quarters

Remarks

It is obvious from past and present records that mangroves reach the southern limit of their distribution on the east coast of Africa in the Transkei.

Small colonies of *Bruguiera gymnorrhiza* and *Avicennia marina* exist in specially favoured localities as far south as the Kei River Mouth, but generally these colonies are of very limited extent and constitute too small a part of the coastal vegetation

to replicate the very important role they fill on more tropical coasts in recovering and protecting land from the sea.

It is reasonable to suppose that the existence of these small colonies growing at about the limit of their climatic range is a precarious one. The recent establishment of the Bashee Colony suggests that it may be one of a series of recolonisations. Extended observation of typical southern mangrove communities may show that they are periodically killed out or decimated by unfavourable seasons and re-established by fruits carried south in the marine drift.

ACKNOWLEDGMENTS

The writer is indebted to the Chief of the Division of Botany and Plant Pathology; to Miss I. C. Verdoorn, of the National Herbarium, Pretoria; to Miss H. Forbes, of the Natal Herbarium, Durban; and to Miss G. Britten, of the Albany Museum Herbarium, Grahamstown, for assistance and records.

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INDEX TO ILLUSTRATIONS.

Photo 1: The Avicennia marina community at Bashee Mouth. The mangroves are invading a *Salicornia sp.* consocies on mud flats. The coarse sedges *(Scirpus littoralis* and *Juncus maritimus)* in the foreground are on higher ground and represent a later stage in the succession. The large tree of Group 1 is on the left, while the smaller tree belonging to Group 2 can be seen on the right.

Photo 2: The Avicennia marina community at Bashee Mouth. Young *Avicennia marina* trees in the foreground and middle distance. The large tree on the right belongs to Group 2. The shadow to the left is cast by the Group 1 tree.

Photo 3: The Avicennia marina community at Bashee Mouth. Young *A. marina* and a solitary *Bruguiera gymnorrhiza* are seen in the foreground.

PHOTO 1

PHOTO 2

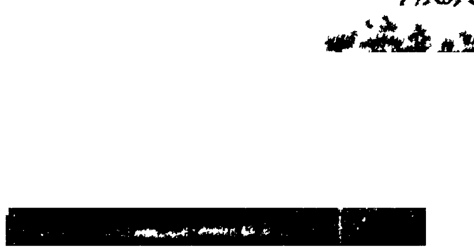

PHOTO 3

South African Journal of Science, *Vol. XLI, pp. 243-244, February, 1945.*

POISONING OF ANIMALS AND HUMAN BEINGS BY ALGAE

BY

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Read 3rd July, 1944.

As an article supplying full details of the identification, description and active principles of the alga (species of *Microcystis*) and of the symptoms and pathological lesions induced by it, is being prepared for publication in the Onderstepoort Journal of Veterinary Science and Animal Industry, only a résumé of some of the most important aspects will be given here.

In South Africa the first cases of poisoning with algae in stock, rabbits and water birds were diagnosed in 1927 in the Amersfoort district. However, recent investigations indicate that in the north-eastern Free State and south-eastern Transvaal many thousands of stock, mainly sheep and cattle, have died from algae poisoning during the last twenty-five to thirty years.

Within two years after the completion of Vaal Dam, stock in its immediate vicinity began to die from an unknown disease. Subsequent investigations proved that this disease was caused by drinking water heavily contaminated with a poisonous alga, identified by Miss Edith Stephens, of the University of Cape Town, as a species of *Microcystis*. Miss Stephens is continuing her studies on the *Microcystis* in order to determine the species. It was proved experimentally that (a) the fresh, growing algae are poisonous, and that they discharge their poison into the water when they die off; (b) decomposition of the masses of dead algae reduces their toxicity; (c) boiling the water contaminated with the algae does not reduce its toxicity; and (d) experimental animals drenched with the contaminated water developed the same symptoms and pathological lesions as those observed in stock drinking in Vaal Dam.

The poisonous *Microcystis* is a minute, unicellular plant growing in the water and forming globules approximately the size of a pin's head. During calm and warm weather the algae collect in green masses on the surface of the water (water-bloom), while in cold weather they are found at various depths under the water. Winds blow the water-bloom to the edge of the water where, under conditions favourable to its growth, it collects in tremendous quantities and, if not removed by a

change in the direction of the wind, these masses decompose. During the process of decomposition a most offensive odour is emitted and a beautiful play of colours, varying from dark green to different shades of blue, purple and dark red, develops. The water filtered off from these decomposing masses is fluorescent (blue-purple-red) due to the presence of a pigment called *phycocyan*, isolated by Dr. Polson, of Onderstepoort.

Toxic Principles of the Mycrocystis.

This alga appears to contain two active principles, namely, a most potent liver poison and a photosensitising agent (*phycocyan*). Mr. P. G. J. Louw, chemist, Onderstepoort, is engaged upon the isolation of the liver poison.

Symptoms of Poisoning.

Horses, cattle, sheep, dogs, turkeys, ducks and fish have died from the *Microcystis*. If large quantities of the alga are consumed, the animals (usually cattle and sheep) are found dead near the edge of the water. They die from acute general paralysis or with strychnine-like convulsions. If smaller quantities of the contaminated water are taken, the affected animals usually show (a) a certain degree of constipation, the hard faeces being covered with blood; (b) drop in milk yield; (c) general weakness; and (d) signs of burning (photosensitisation) of the skin by the sun. In the more protracted cases there may be jaundice as a result of damage to the liver.

In the United States of America suspected cases of algae poisoning have occurred among human beings drinking water infected with *Microcystis flos-aquae*.

Post Mortem Appearances.

These can be correlated with the symptoms described above.

Treatment.

Symptomatic treatment should be applied (enemata, purgatives, heart stimulants, provision of shade, liniments for the skin lesions).

Eradication of the Alga.

It can be very successfully destroyed by copper sulphate in dilutions of 1lb. to every two hundred thousand gallons of water

South African Journal of Science, *Vol. XLI, pp. 245-268, February, 1945.*

CRANIAL ANATOMY AND ONTOGENY OF THE SOUTH AFRICAN CORDYLID *CHAMAESAURA ANGUINA*

BY

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Zoological Institute, University of Stellenbosch.

With 11 Text Figures.

Read 4th July, 1944.

Introduction.

The genus *Chamaesaura* is usually placed in the family Zonuridae. In Dr. V. FitzSimon's monograph on the South African Lacertilia, "Zonuridae" has been superseded by "Cordylidae." In a personal communication he has kindly set forth the reasons for the change in the nomenclature of the family, and although it would be unfair to enumerate his arguments the reasons adduced by Dr. FitzSimons for the taxonomic change are logical and convincing and will be adopted in this paper. Details of the taxonomic position of the genus *Chamaesaura* will appear in Dr. FitzSimon's monograph; suffice it to say that the genus was instituted by Schneider in 1799. The species *C. anguina* appears in Linnaeus's Systema Naturae, 10th edition, under the name *Lacerta anguina*, and the species *C. macrolepis* was described by the American batrachologist Cope in 1862.

The adult *C. anguina* was captured by Professor de Villiers in the Bredasdorp district. The embryos of *C. anguina* and *C. macrolepis* were kindly supplied by Dr. V. FitzSimons. The adults from which the embryos were taken were captured near Pretoria, and at Ubombo, Zululand.

The specimen of *Cordylus* (generic name re-instated by Dr. FitzSimons for the genus *Zonurus*) was taken by Professor de Villiers in the Caledon district and identified as *Cordylus polyzonus*.

The adults of *Chamaesaura anguina* and *Cordylus polyzonus* were microtomised and stained with Van Gieson's solution by Professor de Villiers. The embryos of *C. anguina* and *C. macrolepis* were decalcified in Ebner's solution for five days, bulk-stained in borax-carmine and counter-stained with azan. Drawings made with the aid of the Panphot projection apparatus were utilised in the preparation of the reconstructions figured.

I want to express my thanks to Professor de Villiers for his valuable advice and guidance, and to Dr. V. FitzSimons for the gift of the very valuable embryological material.

Dr. FitzSimons has very kindly granted me permission to use the taxonomic details referred to above.

The Present Investigation.

Nasal Region: As may be expected the cartilaginous nasal skeleton differs very little from that of *Lacerta agilis*, described by Gaupp (1900). The tectum nasi and the side-walls of the nasal capsule are largely retained. The septum nasi is prolonged anteriorly, reaching beyond the cupolae anteriores in the shape of a wedge-like rostrum ensheathed by the fused premaxillaries. In the Iguanidae a similar, though much shorter rostrum exists. In *Cordylus* and *Platysaurus* it is absent. A large fenestra dorsalis as well as a fenestra lateralis is present. The duct from the glandula nasalis lateralis enters the nasal sac through a lateral foramen which is probably formed by the fusion of the processus alaris superior to the anterior edge of the zona annularis (Fig. 3). The lamina transversalis anterior is postero-laterally inclined. That portion forming the ventral support of Jacobson's organ possesses a ventrally directed ridge which is prolonged backwards as the cartilago ectochoanalis.

In the Gaupp-Ziegler model of the skull of the embryo *Lacerta agilis* the cartilago paraseptalis is present as a ribbon of cartilage stretching from the lamina transversalis anterior to the planum antorbitale, but this structure is absent in *Chamaesaura*. Apart from the lamina transversalis anterior the only remains of the solum nasi lie immediately behind the organ of Jacobson as two pieces of cartilage situated between the vomer and septomaxillary; in late embryos of *Chamaesaura* it is absent so that it presumably develops in the juvenile (cp. Malan, 1940, for *Gerrhosaurus*). Malan (1940) described a somewhat similar structure for *Gerrhosaurus* in which it is continuous with the anterior paraseptal cartilage. She named it "plexus cartilaginis paraseptalis" regarding it as probably "a local development of the cartilago paraseptalis for strengthening the posterior wall of the organ of Jacobson, and particularly for the protection of the nerve fibres innervating the organ" (p. 194). Although differently shaped this plexus is also present in *Mabuia*, *Lacerta* (Malan, 1940), *Platysaurus* and *Cordylus*. After entering the nasal cavity through the fissura orbitonasalis the ramus profundus of the trigeminal nerve splits into a ramus medialis and a ramus lateralis nasi. The former runs forwards against the nasal septum, whereas the latter turns laterally below the tectum nasi and leaves the nasal cavity through the foramen epiphaniale, situated dorsally to the aditus conchae, to innervate the lateral nasal gland; it then pierces the dorsal process of the maxillary to innervate the skin. The ramus medialis pierces the septomaxillary and emerges from the nasal cavity through the foramen apicale situated in the cupola anterior.

Jacobson's Organ: The septomaxillary constitutes the anterior, dorsal and part of the lateral wall of the skeletal capsule of the organ. The paraseptal cartilage is absent so that

the medial wall is formed by the septum nasi and the vertical portion of the vomer. The anterior half of the organ rests upon the zona annularis " which forms a cushion of cartilage ("pilzförmiger Wulst ") in the centre of the organ " (Malan, 1940, p.193), whereas behind the opening the vomer forms the floor of the capsule. Posterior to the organ lies the cartilaginous plexus described above (Fig. 5).

The filling of the organ with fluid from the oral cavity is probably brought about in the manner described by Broman for Lacertilia. Pressure applied laterally to the opening of the organ will push the zona annularis and its cushion of cartilage upwards and result in the discharge of the contents of the lumen into the buccal cavity. When, by release of the pressure, the floor of the organ regains its normal position, fluid from the oral cavity will be sucked into the lumen. Broman (1919) states that in Lacertilia the ductus nasolacrimalis opens into the duct of Jacobson's organ, thus supplying fluid for the filling of the organ; in *Chamaesaura*, however, this duct opens into the " Choanenrinne " (Fuchs, 1908). In the region of the opening of Jacobson's organ the diverging dorsal ridges of the vomers form a trough below the nasal septum. On account of the trough being filled with very loose connective tissue a dorsal displacement of the vomers by pressure exerted on the palate is possible. This probably effects a narrowing of the lumen. Further evidence for Broman's theory is the circumstance that the septomaxillary lies closely applied to the nasal septum whereas anteriorly it is contiguous with the zona annularis (Fig. 4) (cp. Malan, 1940, for *Gerrhosaurus*). This may be the result of pressure exerted upon the septomaxillary and the zona annularis. Moreover the glandulae vomerales posteriores on the " Vomerpolster " behind behind the openings of these organs are solely represented by crypts, lined with goblet cells, in the oral epithelium.

THE GLANDS OF THE BUCCAL CAVITY: The momenclature used for the different glands is that of Fahrenholz (1937).

The glandulae vomerales anteriores are represented by a well-developed glandular mass lying anterior to the openings of Jacobson's organs. The glandulae vomerales posteriores, lying behind openings of these organs are solely represented by crypts, lined with goblet cells, in the oral epithelium.

The glandulae palatinae lie along the upper jaws mesial to the teeth and stretch from the glandulae vomerales anteriores to the region lateral to the choanae.

The glandulae mandibulares are well-developed glands situated in the anterior region of the floor of the oral cavity and opening below the tongue. The lateral mandibular glands are either absent or fused to the medial ones. The glandulae labiales inferiores stretch along the lateral sides of the lower jaws from the symphysial region to the angle of the mouth.

Glandulae sphenopterygoideae are ill-developed and appear as two narrow strips of glandular epithelium lateral to the pterygoids and palatines.

The secretory cells on the tongue are situated in crypts. The glandulae labiales superiores and crico-arytaenoideae are absent.

Dermal Cranial Bones.

The *premaxillaries* are fused except for the posterior halves of their palatal portions which are separated by connective tissue (Fig. 2). The bone contains a niche-like sheath for the reception of the rostrum of the cartilaginous nasal capsule. Dorsally the fused premaxillaries extend backwards as a ridge appearing T-shaped in transverse sections (Fig. 4). The arms of the T overlap the nasals whereas its leg is clasped between them. Anteriorly the bone is pierced by the two rami mediales nasi.

The *maxillary* possesses a well-developed dorsal process stretching from the external naris to the front of the orbit, almost entirely overlapping the anterior portion of the prefrontal. Anteriorly its palatine process forms a lateral support to the anterior parts of the vomer, the septomaxillary and to the cartilago ectochoanalis. Behind the nasal capsule it makes contact with the maxillary process of the palatine. The relations of the maxillary to the transversum and jugal are similar to that of *Lacerta agilis* as reconstructed in the Gaupp-Ziegler model.

The *vomer* is paired. Anteriorly it underlies the short palatal portion of the premaxillary whereas its pointed posterior tip lies in a groove on the ventral surface of the palatine. The vomer is trough-shaped, the trough opening dorso-laterally. Posterior to the opening of Jacobson's organ the vomer extends almost to the maxillary, being separated from the latter by the "Choanenrinne" (Fuchs, 1908).

The *Palatine*: Anteriorly this bone rests in a groove on the dorsal surface of the vomer and posteriorly it lies on the pterygoid. The bone possesses a stout maxillary process abutting against the maxillary. Owing to its dorso-ventral disposition anteriorly it forms the medial wall of the deep groove that connects the orbital groove ("Orbitalmulde," Fuchs, 1908) with the antorbital portion of the nasal sac (Fig. 6). Posteriorly the palatine twists so as to form the roof of the above-mentioned groove. Immediately behind the planum antorbitale the palatine is connected to a ventral flange of the frontal by means of strands of connective tissue. The orbital groove is situated between the divergent posterior portions of the palatines.

The *pterygoid*: Anteriorly the pterygoid overlaps the posterior portion of the palatine; posteriorly it becomes broader and possesses the usual antero-lateral process which is in intimate contact with the transversum (Fig. 1). Behind the basipterygoid process the pterygoid becomes more slender, swinging slightly outwards towards the quadrate.

The medial surface of the foot of the quadrate and the lateral surface of the pterygoid running parallel to it are both covered by layers of connective tissue. Moreover these elements are separated from each other by a space resembling a synovial cavity. This suggests the possibility of a sliding movement of the pterygoid against the quadrate. The posterior tip of the pterygoid is attached to the quadrate by long strands of connective tissue, typical of Lacertilia (Versluijs, 1936).

From the processus maxillaris posterior of the nasal capsule the jugal stretches backwards along the dorsal surface of the maxillary, and behind the orbit it turns upwards to articulate with the postorbital.

The *prefrontal*: The particularly large prefrontal possesses numerous large marrow cavities. Anteriorly it lies across the aditus conchae, where it is almost entirely covered by the dorsal process of the maxillary, whereas posteriorly its greater part is overlain by the supra-orbital bones. Stretching downwards behind the planum antorbitale it forms the anterior border of the orbit, supported medially by a ventral flange of the frontal. The prefrontal possesses three posteriorly directed processes, one lying against the frontal, one ventral and a shorter dorsolateral one, thus forming an anterior protection for the eye (Fig. 1).

In the absence of a lacrimal the ductus nasolacrimalis is supported medially and dorsally by a slight, ventral bifurcation of the prefrontal. The medial part of this fork is continued into the orbit as the above-mentioned ventral process. The lateral part of the fork apparently simulates a lacrimal which is fused to the prefrontal. Laterally and ventrally the nasolacrimal duct is supported by the maxillary.

The *frontals* are fused to a single bone underlying the nasals anteriorly. In the antero-medial corners of the orbits the thickened lateral edges of the unpaired bone possess ventral prolongations, medial to the prefrontal and lateral to the cartilago sphenethmoidalis. This bony flange is attached to the palatine by means of dense connective tissue (Fig. 6). The frontal therefore overlies the olfactory lobes in the form of a hood which becomes shallower posteriorly to be completely straightened out in the region of the planum supraseptale. Posteriorly the frontal articulates with the postfrontal and parietal (Fig. 1).

The *supra-orbital bones* are shown in Fig. 1. They are five in number and are arranged in two rows, the medial of which contains two large bones while the lateral is made up of three smaller ones. An additional bone of the circumorbital type was found in the lower eyelid.

The *parietal*. The relation between the parietal and frontal is shown in Fig. 10. The two posteriorly directed processes of

the frontal rest on the lateral edges of the parietal to which they are connected by means of dense connective tissue. Laterally the frontal also articulates with the postorbital, post-frontal, squamosal and supratemporal. Posteriorly the parietal possesses three backwardly directed processes: one medial and two lateral. The medial one, resting on the supraoccipital splits into two slightly diverging tips lying on both sides of a crest on the posterior portion of the supraoccipital (cp. *Gerrhosaurus*, Malan, 1940). The lateral processes articulate with the squamosals and supratemporals, their posterior tips resting on the cristae paroticae of the auditory capsules. The relations of the parietal to the occipital region will be discussed in detail below.

The parietal eye is well-developed; it is situated below the anterior portion of the parietal and is covered by an extremely thin layer of this bone. The intense pigmentation of the parietal eye made it impossible to study its finer histology or to ascertain whether the organ has undergone degeneration as the result of occlusion of the parietal foramen. According to de Villiers (1939) the organ shows no traces of degeneration in the skink *Acontias* in spite of the parietal foramen being closed over by a bony incrustation. In the embryos of *Chamaesaura* a lens and a heavily pigmented retina were observed.

THE ORBITO-TEMPORAL REGION.

In this region the side-wall of the Lacertilian chondrocranium usually conforms to the typical structure of slender, transverse and upright bars of cartilage as described by Gaupp for *Lacerta* (1900) except in specialised forms like the burrowing *Acontias* (de Villiers, 1938) and *Monopeltis* (Kritzinger, in progress) in which it disappears, being partly or entirely replaced by bone. For detailed descriptions of this region the reader is referred to the works of Gaupp (1900), Rice (1920) and Hafferl (1921). This structure in *Chamaesaura* is essentially similar to that of *Lacerta* described by Gaupp (1900). The posterior portion of the taenia medialis is degenerate, being very thin and interrupted at a point medial to the epipterygoid. The pila prootica is lost so that the fenestra prootica and fenestra metoptica become confluent. Such confluence of the two fenestrae also occurs in *Eumeces* (Rice, 1920) and *Platydactylus* (Hafferl, 1921), so that the reduction of the pila prootica and taenia medialis appears to be a fairly common occurrence among lizards. On the other hand the rest of the side-wall seems to be more constantly retained. In *Chamaesaura*, as in *Lacerta* the pila metoptica ossifies as the orbitosphenoid. This ossification stretches forward along the ventral side of the taenia medialis, thus bordering the fenestra optica posteriorly and dorsally.

THE EPIPTERYGOID.

The epipterygoid is present as a stout bony structure; its cartilaginous dorsal epiphysis does not reach to the pariental or

to the taenia marginalis. The parietal possesses a short, ventrally directed process to which the dorsal tip of the epipterygoid is connected by means of ligamentous tissue lying lateral to the taenia marginalis. Similar relations exist in *Cordylus.*

Ventrally, where the epipterygoid fits into a cavity in the pterygoid, cartilage of the processus ascendens persists (Fig. 7b). At the bottom of this pterygoidal pit lies a group of cartilage cells (Fig. 7b). De Villiers (1939) described a similar, though relatively much larger piece of cartilage for *Acontias meleagris* and regarded it as presumably a derivative of the processus ascendens. This does not appear to be the case in *Chamaesaura*: in a fairly late embryo of *Chamaesaura macrolepis*, in which the synovial cavity between the epipterygoid and the pterygoid is already developed on the one side, the piece of cartilage in question is still absent. This circumstance renders its derivation from the processus ascendens improbable as it would have had to migrate through the synovial cavity, already present, to reach the position occupied in the adult.

On the other hand it may be absent in the adult of this species which was not at my disposal for investigation. In *Cordylus* it is represented only by a few scattered cartilage cells lying in the connective tissue covering of the pterygoid. It is doubtful whether any importance attaches to this small cartilage in *Chamaesaura,* as it seems to be a local chondrification, facilitating movement between the pterygoid and the epipterygoid.

Gaupp (1898) found that in early embryos of *Lacerta agilis* the quadrate, epipterygoid (antipterygoid of Gaupp) meniscus pterygoideus (cartilago articularis ossis pterygoidei of Gaupp) and processus pterygoideus are continuous. Broom (1924) observed for embryos of *Cordylus, Mabuia* and *Eremias* " a well-developed cartilaginous bar fixing the lower end of the quadrate to the lower end of the epipterygoid as in Sphenodon " as well as distinct remains of this bar in *Agama* and *Lophosaura,* though in the two latter genera it is no longer chondrified. In the adults of *Chamaesaura* and *Cordylus* the anterior portion of this bar is present as a slender rod lying in a groove on the dorsal surface of the pterygoid. For obvious reasons its connection with the epipterygoid is lost. In the embryo of *Chamaesaura macrolepis* this piece of cartilage is relatively larger and still slightly continuous with the epipterygoid.

The processus pterygoideus is retained in the adults of both species; it is present as a slender bar of cartilage lying on the dorsal surface of the pterygoid. Posteriorly it reaches to the synovial joint between pterygoid and epipterygoid, and is medially flexed so that its posterior tip lies medial to the base of the epipterygoid. In this region it is continuous with the anterior portion of the meniscus pterygoideus. The connection is more extensive in *Cordylus,* in which the posterior tip of the processus ptyerygoideus bifurcates to form lateral and medial pro-

longations ensheathing the base of the epipterygoid. Fig. 7a shows its relations in the embryo of *Chamaesaura macrolepis* in which processus pterygoideus, epipterygoid and meniscus pterygoideus exist in synchondrotic continuity.

In both *Chamaesaura* and *Cordylus* the meniscus pterygoideus is a plate of cartilage covering the medial face of the pterygoid to which it is closely applied. Anteriorly it extends beyond the processus basipterygoideus (Fig. 2).

The Cranial Base.

The parasphenoid and the basisphenoid are fused to each other so that the arteria carotis interna and the palatine nerve, lying between these two elements in the embryo, are enclosed in a parabasal canal. Immediately prior to leaving the basis cranii at the base of the basipterygoid process the internal carotid artery gives off a branch entering the cranial cavity at a point lateral to the posterior portion of the hypophysis, and supplying the brain.

At about the middle of its length the cranial base possesses a pair of osseous squames (Fig. 2). These are separated from the skull base by means of a thin layer of connective tissue and they overlie the cartilaginous sutures representing the boundaries between cranial base and ossa prootica (Fig. 8). The internal carotid arteries and palatine nerves enter the parabasal canals through foramina situated between the antero-lateral edges of these bony processes and the basisphenoid. Reference to an embryo of *Cordylus* in which the posterior portion of the parasphenoid was not yet fused to the basisphenoid proved that these blades of bone are posterior prolongations of the membrane bone only; corroborative evidence is afforded by the relations to the internal carotid arteries and the palatine nerves. According to Siebenrock (1892) similar, though longer processes are present in the Skinkids *Eumeces* and *Lygosoma* and in the Anguid *Ophisaurus*. Malan (1940) described these processes for the genus *Gerrhosaurus*, naming them "processûs posteriores of basisphenoid." Examination of Miss Malan's material proved that the relations of these structures to the rest of the skull base and to the internal carotid arteries are similar to those in *Chamaesaura* and *Cordylus*. Embryological material will be necessary to substantiate Malan's implied contention of the basisphenoidal origin of these processes in *Gerrhosaurus*.

The short rostrum parasphenoidale of *Chamaesaura* is very thin and surrounded by dense connective tissue. The processus basipterygoideus attaches to the anterior corner of the cranial base and is antero-laterally directed. Between the anterior portion of its broad cartilaginous epiphysis and the pterygoid is situated the meniscus pterygoideus described above. This meniscal cartilage and the basipterygoid process are separated from each other by a synovial cavity.

In the Lacertilian embryo the basal plate is perforated by a large fenestra basicranialis posterior, of which the anterior portion is closed by the underlying parasphenoid. Later in the ontogeny the posterior portion also becomes closed (Versluijs, 1936). In the adult *Chamaesaura* the basis cranii is perforated medially by a pair of fenestrae situated between the posterior processes of the parasphenoid described above (Figs. 2 and 8) *Cordylus* possesses an unpaired, larger fenestra in the same position. A comparison of adults with embryos of both genera leads to the conclusion that such fenestrae are derivatives of the fenestra basicranialis posterior.

The boundary between the basisphenoid and the basioccipital cannot be ascertained for either *Cordylus* or *Chamaesaura*. The occipital condyle is formed by the exoccipitals and the basioccipital. In the embryo of *Chamaesaura* these elements can be distinguished as three distinct centres of ossification, separated from one another by means of tracts of cartilage, meeting posteriorly and continuous with the cartilaginous sutures between basis cranii and ossa prootica. In the adult these cartilage sutures becomes discontinuous behind the tubercula sphenoccipitalia, while between the occipital elements they are reduced to vestiges not completely separating the basioccipital from the exoccipitals In the adult *Cordylus* these sutures of cartilage persist everywhere.

The Temporal Region.

The problem of the homology of the two temporal bones present in Lacertilia has been discussed by many authors, e.g Gaupp (1894), Thyng (1906), Versluijs (1936), Brock (1935) Gaupp's contention that the Mammalian squamosal is homologous with the inner of the two Lacertilian elements was apparently disproved by Thyng (1906), whose work, however, lacks recent confirmation. Thyng found that the Mammalian squamosal was primarily a membrane bone on the pars quadrata (incus of Mammalia) and not on the otic capsule as maintained by Parker and accepted by Gaupp. In this work the late Professor Versluijs's nomenclature will be used; squamosal for the outer and supratemporal for the inner element of the Lacertilian temporal region.

Chamaesaura possesses a single temporal arch consisting of the postfrontal, a large postorbital and the squamosal and both postfrontal and postorbital help to form the posterior border of the orbit (Fig. 1). Loose connective tissue connects the postorbital to the dorsal tip of the jugal. A slender anterior prolongation of the squamosal articulates with the lateral edge of the postorbital. The small supratemporal fossa is bounded anteriorly by the postorbital, medially by the parietal and posteriorly and laterally by the squamosal (Fig. 1). Broom (1935) figures two Cordylid genera: *Cordylus vittifer* (*Zonurus vittifer* of Broom) and *Platysaurus guttatus*, neither of which possesses a supra-

temporal fossa. In the species of *Cordylus* that was compared with *Chamaesaura* there exists immediately behind the postorbital a narrow slit about 850μ in length between the squamosal and the parietal. This might simulate a supratemporal fossa in the process of being closed up by progressive development of the surrounding bones. Behind the supratemporal fossa of *Chamaesaura* the squamosal broadens out medially to articulate with the lateral process of the parietal. Posteriorly the lateral edge of the squamosal is flexed ventrally so as to rest on the head of the quadrate to which it is attached by means of connective tissue. The inner bone, or supratemporal, is wedged between the posterior part of the quadrate head and the crista parotica and rests with its ventral edge on the intercalary. In the adult *Chamaesaura anguina*, an extra temporal bone was observed on the one side (Fig. 1). It is situated between the squamosal and the supratemporal and dorsal to the head of the quadrate. The presence of this bone is probably abnormal, since it is absent in both embryos of *Chamaesaura* examined.

In *Cordylus*, as in many other lizards, there is a synovial cavity between the intercalary and quadrate, facilitating movement between these two elements. In *Chamaesaura* this synovial cavity is replaced by a thin layer of dense connective tissue (Fig. 11). The intercalary is comparatively much smaller than that of *Cordylus* and lies closely applied to the ventral edge of the supratemporal which seems to invade the cartilage of this element on one side of the head. In *Cordylus* and in the embryo of *Chamaesaura anguina* the cartilage of the intercalary was found to be continuous posteriorly with that of the parotic process of the crista parotica. A ligament attaches the intercalary to the insertional plate ("Insertionsteil" of Versluijs, 1903) of the extra-columellar. Judging from its size and its relations to the surrounding elements it would appear that the function, ascribed to the intercalary by Versluijs: that of meniscal cartilage between the quadrate and the otic capsule, has been lost in *Chamaesaura* (Fig. 11).

The quadrate conforms to the normal Lacertilian type: in contrast to that of *Cordylus* it is very slightly excavated laterally; its slightly concave ventral end fits on to the articular facet of the lower jaw and its head leans against the otic capsule and the supratemporal. Cartilage persist at both ends of the quadrate.

The well-developed middle ear communicates with the pharynx through the Eustachian tube. There is a normal auditory apparatus consisting of a bony stapes, fitting into the fenestra ovalis by means of a footplate, surrounded by cartilage, and an extra-columellar possessing a slender processus internus reaching to the quadrate. After leaving the nervus facialis, the chorda tympani passes forward dorsal and in close proximity to the processus internus to descend to the lower jaw on the lateral side of the tip of this process.

Except for sutures of cartilage between the prootic, supra-occipital and basisphenoid there are no indications of boundaries between the elements comprising the otic capsules. The cartilage between the supra-occipital and prootic is continuous with that of the taenia marginalis. *Cordylus* exhibits what appears in section as a membrane bone on the prootic and lying dorsal to the stapes. It proved to be a bony splint of the prootic, forked posteriorly and separated from this bone by connective tissue. The posteriorly directed prootic splint simulates a membrane bone when seen in transverse sections. The additional membrane bone present on one side of the head in *Chamaesaura* has quite a different position apart from its being of a truly dermal nature. The presence of these abnormalities in the temporal region of the Cordylidae was thought worthy of being recorded, as the temporal region of the Lacertilian stock must have included more than two membrane bones, further reduced to a single one in the living Rhynchocephalia.

The relation between the processus ascendens tecti synotici and the overlying parietal indicates that metakinesis is possible in the skull of *Chamaesaura*. The processus ascendens tecti synotici stretches forward beyond the otic capsule; its anterior portion, firmly attached to the parietal, lies in a shallow groove within this bone. As this groove becomes shallower posteriorly, the parietal becomes thicker in the median line, thus forming a low osseous cushion in which the shallow trough for the processus ascendens tecti synotici is lodged (Fig. 9b). Posteriorly the tract of connective tissue between the parietal and the underlying chondrocranial roof becomes wider and less dense and above the supra-occipital it reaches its maximal width and looseness of histological texture. Here the parietal rests on the median crest of the supra-occipital and the trough overlying the processus ascendens tecti synotici anteriorly is straightened out. More posteriorly this supra-occipital crest becomes more prominent and is covered by very dense connective tissue. In this region the posterior tips of the median process of the parietal diverge from the supra-occipital crest and afford attachment to certain muscles. The relations between the lateral process of the parietal, the temporal bones and the auditory capsule are such as would not impede metakinetic function, provided that the movements are slight (cp. Versluijs, 1936). A small amount of movement may be possible between the temporal bones on the one hand and the quadrate and the auditory region on the other on account of the presence of abundant connective tissue between them.

The relations of the parietal to the chondrocranial roof of *Cordylus* are essentially similar to those described for *Chamaesaura*. The ventromedial prominence of the parietal is, however, better developed and covered by a layer of dense connective tissue possibly facilitating movement of the parietal over the

supra-occipital. The medial process of the parietal is forked posteriorly, stretches backwards beyond the occipital condyle, and is accompanied by a spine of the supra-occipital on which it rests. The same is true of the crista parotica and neighbouring structures.

The Lower Jaw.

The lower jaw is typically Lacertilian. The seven bones enumerated by Versluijs (1936) are all present in their normal relations to one another. The gonial and the supra-angular are both fused to the articular but not with each other. The processus retro-articularis is formed by the fused gonial and articular. The dorsal surface of the latter is covered with cartilage and fits into a shallow trough on the ventral surface of the quadrate.

The chorda tympani enters the lower jaw through a foramen on the medial surface of the gonial. Anterior to the articular the nerve lies in the canal for Meckel's cartilage and accompanies the ramus mandibularis of the trigeminal nerve with which it forms an anastomosis. The nervus mylohyoideus pierces the angular ventrally while the n. auriculo-temporalis passes through a foramen in the supra-angular immediately posterior to the articulation of the latter with the dentary. In some forms e.g. *Physignathus* (Fuchs, 1931), the foramen is situated between the supra-angular and the dentary. The latter bone is pierced by numerous branches of the mandibular nerve.

Anteriorly the canal for Meckel's cartilage becomes converted into an open groove lying on the inner surface of the lower jaw. In the embryos of *Chamaesaura* the cartilages of Meckel are in synchondrotic continuity and the dentaries are connected by means of dense connective tissue. In the adult of *Chamaesaura* this region was slightly damaged so that the histological details of the symphysial region could not be ascertained.

The Cranial Kinesis.

For our knowledge of the cranial kinesis in Reptiles we are largely indebted to the researches of the late Professor Versluijs ("Das Streptostylie—Problem," 1912). The kinesis of *Chamaesaura* will be treated by discussing the relations of the different elements directly concerned with such movements; this is the method adopted by Versluijs (1912).

With the exception of the aberrant Chamaeleons, the Amphisbaenidae and burrowing Skinks like *Acontias* (de Villiers, 1939), the Lacertilian skull is of the type which Versluijs calls "metakinetic." According to this author the oldest Sauropsida, e.g. some Cotylosauria already possessed a metakinetic skull, so that such metakinesis is the primitive condition from which other types of kinesis, and akinesis evolved.

The muscles concerned with kinesis, the musculus protractor pterygoidei and the m. pterygoparietalis (m. levator-pterygodei

of Lakjer, 1927) are present in *Chamaesaura* and *Cordylus*. Ventrally the m. levator pterygoidei inserts on the pterygoid and the meniscus pterygoideus; above the taenia medialis it is attached to the membranous side-wall of the skull which is strengthened by a long ligament lying between the point of insertion of the muscle and the parietal. Versluijs (1912) could not ascribe a definite function to this muscle; Lakjer (1927) states that it lifts the pterygoid. This seems to be its only possible function as it is vertically disposed. The m. protractor pterygoidei stretches between the posterior portion of the pterygoid and the anterior portion of the cranial base, and part of it inserts on the basi-pterygoid process, thus serving to pull the pterygoid forward (Versluijs, 1912, p. 596). This circumstance calls for a movable attachment of the pterygoid to the quadrate. The posterior end of the pterygoid lies along the foot of the quadrate; the surfaces of these two elements facing each other are covered with connective tissue only and are separated by a space resembling a synovial cavity; the posterior tip of the pterygoid is attached to the quadrate by strong connective tissue In a metakinetic skull movement between these two elements will largely eliminate the movement of the quadrate against the otic capsule.

The relation of the pterygoid to the cranial base is of primary importance in any type of kinetic skull; a firm connection of these two elements making kinesis impossible. In *Chamaesaura* there is a synovial cavity between the meniscus pterygoideus and the cartilaginous epiphysis of the basipterygoid process. As in typical metakinetic skulls the epipterygoid in *Chamaesaura* is loosely attached to the parietal and articulates with the pterygoid. Secondary akinesis in *Sphenodon* leads to a firm connection of the epipterygoid with the parietal, whereas in the similarly akinetic Chelonian skull this element is replaced by downgrowths of the parietal. The rigid palate transfers the forward movement of the pterygoid to the nasal region which is rotated and subsequently lifted to afford a wider opening of the mouth (cp. Versluijs, 1912). Such lifting of the snout results in the backward shifting of the membrane bones of the cranial roof. In *Chamaesaura* the nasals, fused frontals and fused parietals are so firmly cemented together that a mesokinetic joint is not represented.

In *Cordylus*, however, abundant connective tissue separates the frontal from the parietal; the former bone possesses on each side a backwardly directed process as in *Chamaesaura*, but whereas in the latter genus these posterior prolongations of the frontal rest on the parietal, in *Cordylus* they fit into lateral grooves in this bone and are surrounded by broad tracts of loose connective tissue. The mesokinetic " Beugungslinie " makes the kinesis of *Cordylus* of the amphikinetic type and is probably responsible for the development of a synovial cavity between the quadrate and the intercalary. Bending of the skull at the

mesokinetic joint would strain the connection between the quadrate and the auditory capsule and lead to a looser connection between them (Versluijs, 1912). It is difficult to ascertain whether the amphikinesis of *Cordylus* is derived from a metakinetic type such as prevails in *Chamaesaura* or whether the latter, a much more specialised form, has secondarily lost its mesokinetic joint. We know that metakinesis is the primitive Reptilian type, but it is not possible to state with certainty that the original Lacertilian stock had already acquired mesokinesis as well as metakinesis. If this should prove to be the case *Cordylus* would exhibit the more primitive type of Lacertilian kinesis, but the study of comparative cranial kinetics of the reptile skull may be considered to be still in its infancy and the problem cannot yet be solved.

According to Versluijs (1912) much of the pressure exerted on the cranial roof by the lifting of the nasal region is absorbed, so that the movement in the metakinetic joint is restricted to " eine kleine Stellungsanderung der Parietalia gegen das Supraokzipitale " (Versluijs, 1936, p. 744). The slight movement of the parietal over the supra-occipital is facilitated by the presence of a thick layer of loose connective tissue between these two elements (Fig. 9c). Movement here is accompanied by a slight movement of the lateral process of the parietal and the temporal bones against the otic capsule.

According to Versluijs (1912), kinesis is an adaptation associated with the wider opening of the mouth, necessitated by the animal feeding upon fast-moving prey. *Chamaesaura* is an agile lizard, living among grass, reeds and low shrubs, and preying mainly on grass-hoppers and other insects (Rose, 1929). It may be assumed that its kinesis is an adaptation to its mode of life and more particularly to its method of catching fast-moving prey.

Summary.

1. The nasal septum is prolonged beyond the cupolae anteriores in the shape of a rostrum which is ensheathed by the fused premaxillaries.

2. The cartilago alaris superior appears to be absent, but is probably fused to the posterior wall of the fenestra narina. This would account for the presence of a foramen through which the duct from the lateral nasal gland passes.

3. The cartilago paraseptalis is absent.

4. A small cartilage situated immediately behind Jacobson's organ develops late in ontogeny.

5. The nasolacrimal duct opens into the " Choanenrinne " (Fuchs, 1908).

6. All the glands of the buccal cavity are present except the gl. labiales superiores. The glandulae sphenopterygoidei and vomerales posteriores are poorly developed.

7. The lacrimal is probably incorporated in the prefrontal.

8. A parietal foramen is absent.

9. The epipterygoid is loosely attached to the parietal by means of ligamentous tissue.

10. The anterior portion of the cartilaginous bar which connects the quadrate and the epipterygoid in the embryo persists in the adult.

11. The processus pterygoideus and the meniscus pterygoideus is in synchondrotic continuity.

12. The parasphenoid is not completely fused to the basisphenoid. The rostrum parasphenoidale is short and extremely thin.

13. The fenestra basicranialis posterior is not completely closed by bone during ontogeny.

14. A small supratemporal fossa is present.

15. The synovial cavity usually found between the intercalary and the quadrate in Lizard skulls is absent.

16. The skull is metakinetic.

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INDEX TO FIGURES AND ABBREVIATIONS.

Fig. 1: Graphical reconstruction of the skull—dorsal aspect.

Fig. 2: Graphical reconstruction of the skull—ventral aspect (Teeth not reconstructed).

Fig. 3: Graphical reconstruction of nasal capsule—ventral aspect.

Fig. 4: Transverse section through the anterior nasal region.

Fig. 5: Transverse section through the region immediately behind Jacobson's organ.

Fig. 6: Section through the anterior corner of the orbit.

Fig. 7: Sections through the lower end of the epipterygoid of (A) an embryo of *Chamaesaura macrolepis* and (B) an adult *C. anguina.*

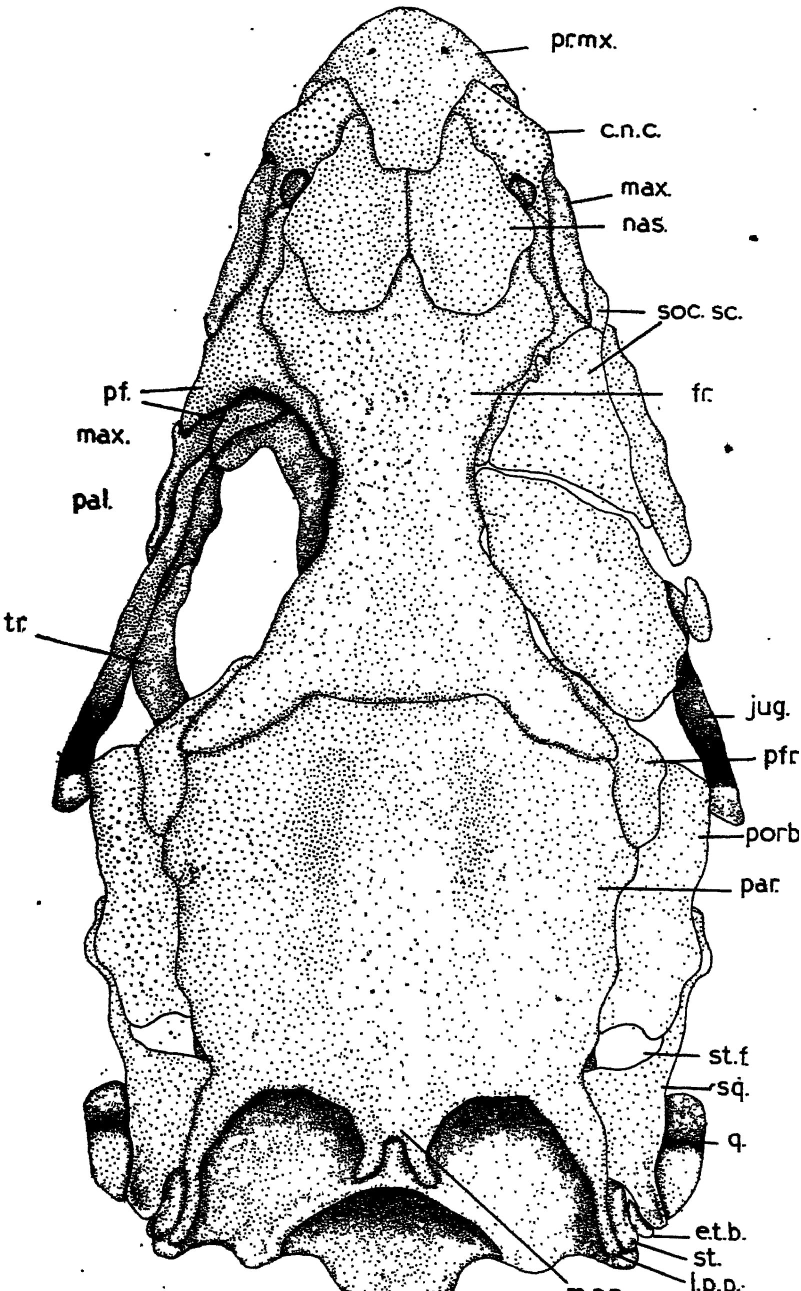
Fig. 8: Sections through the perforated cranial base of (A) *Cordylus* and (B) *Chamaesaura anguina.*

Fig. 9: Consecutive sections through the parietal to show its relations to (A) the anterior, (B) the posterior portion of the processus ascendens tecti synotici and (C) to the supraoccipital.

Fig. 10: Section through the fronto-parietal articulation in the adult *Chamaesaura anguina.*

Fig. 11: Section through the temporal region of an embryo of *C. anguina.*

a.c.i.=arteria carotis interna; bas.=basisphenoid; b.pr.=basipterygoid process; c=concha; c.a.=columella auris; c.ect.=cartilago ectochoanalis; c.p.=crista parotica; chr.="Choanenrinne"; c.J.o= cartilage behind Jacobson's organ; c.n.c.=cartilaginous nasal capsule; c.se.=cartilago sphenethmoidalis; c.t.=connective tissue; d.nl=nasolacrimal duct; ept.=epipterygoid; erect.t.=erectile tissue around naris externa; e.t.b.=extra temporal bone; for.=foramen in floor of concha; fr.=frontal; gl. pal.=glandulae palatinae; gl.v.ant.= glandulae vomerales anteriores; H.gl.=Harder's gland; ic.=intercalary; jug.=jugal; l.p.p.=lateral process of parietal; max.=maxillary; m.p.p.=medial process of parietal; m.pt.=meniscus pterygoideus; nas.=nasal; n.olf.=nervus olfactorius; n.p.=nervus palatinus, o.J.=organ of Jacobson; o.o.J.=opening of Jacobson's organ; os.= orbitosphenoid; pal.=palatine; par.=parietal; pars.=parasphenoid; pf.=prefrontal; pfr.=postfrontal; pl.ant.=planum antorbitale; p.m.a.=processus maxillaris anterior; p.m.p.=processus maxillaris posterior; pr.al.inf.=processus alaris inferior; pr.a.t.c.=processus ascendens tecti synotici; prmx.=premaxillary; porb.=postorbital; p.s.s.=planum supraseptale; pt.=pterygoid; q.=quadrate; r.=rostrum; r.m.=ramus maxillaris v; rmn.=ramus medialis nasi; s.c.=sutural cartilage between basisphenoid and prootic; s.io.=septum interorbitale; sm. = septomaxillary; sn. = septum nasi; soc. = supraoccipital; soc. sc.=supraorbital scales; st.=supratemporal; st.f.=supratemporal fossa; syn.c.=synovial cavity; t. marg.=taenia marginalis; tr.=transversum; v.c.l.=vena capitis lateralis; vom.=vomer; z.a.=zona annularis.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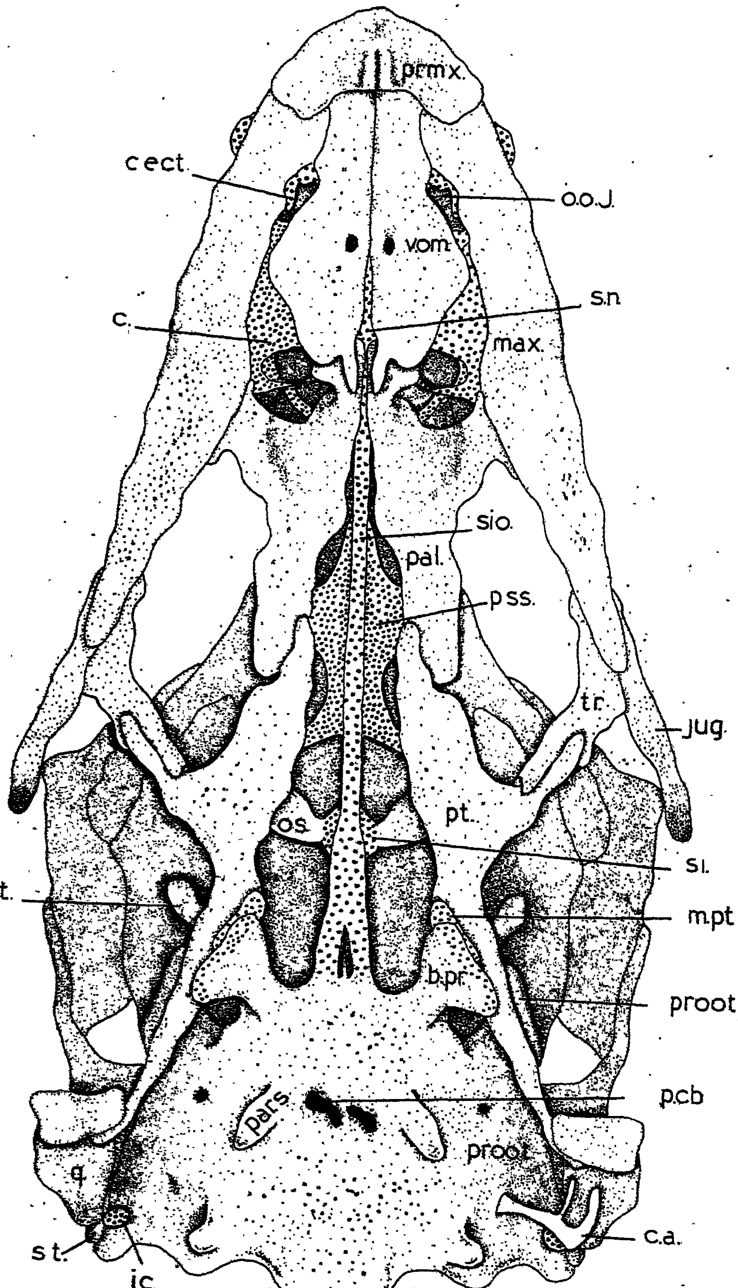

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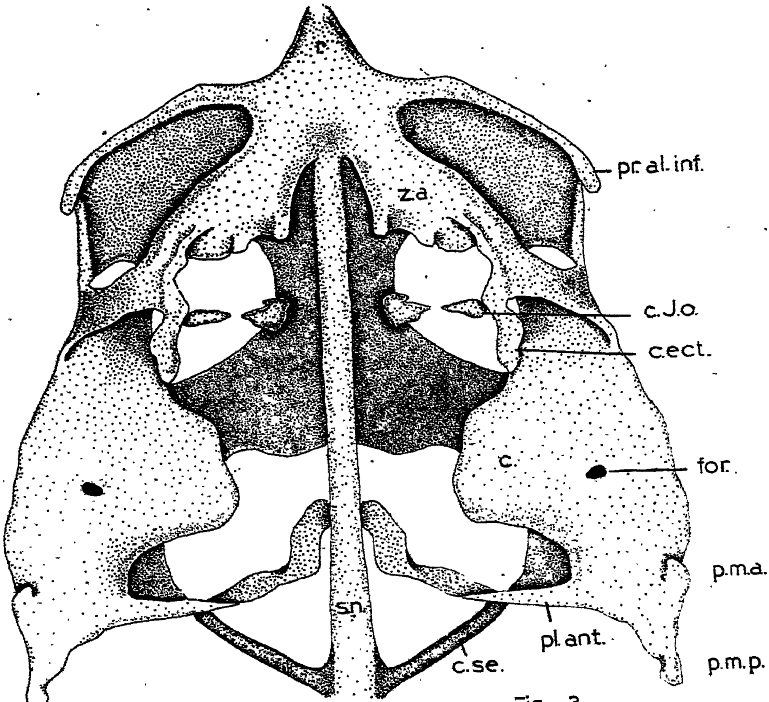
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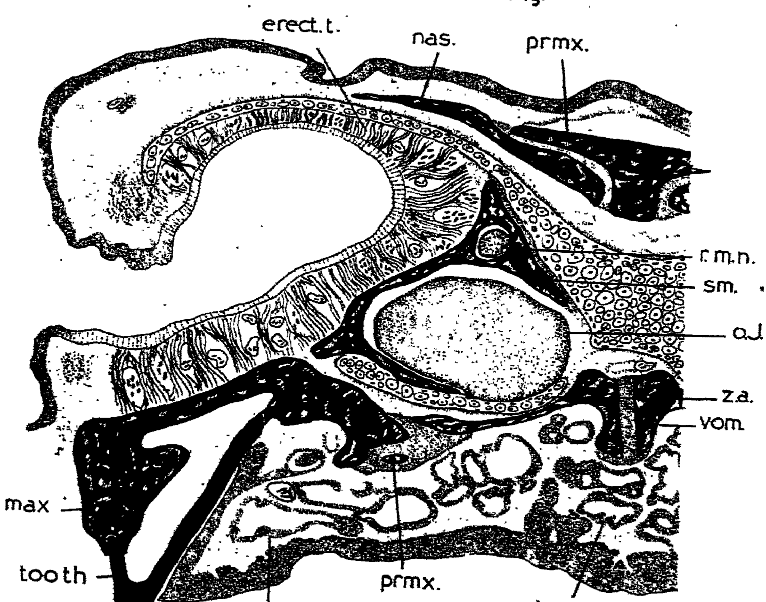
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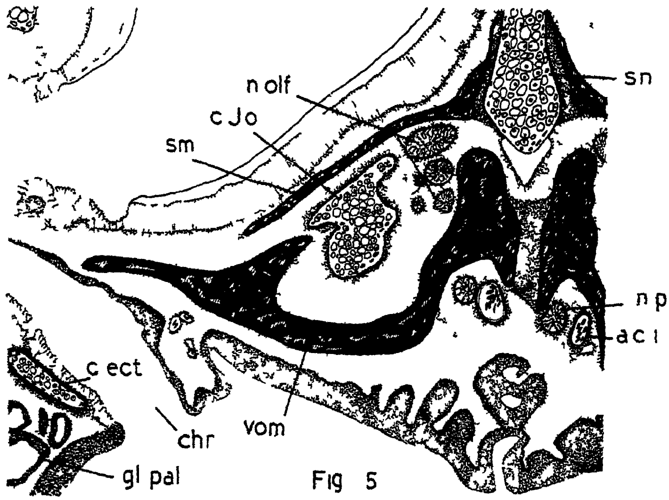
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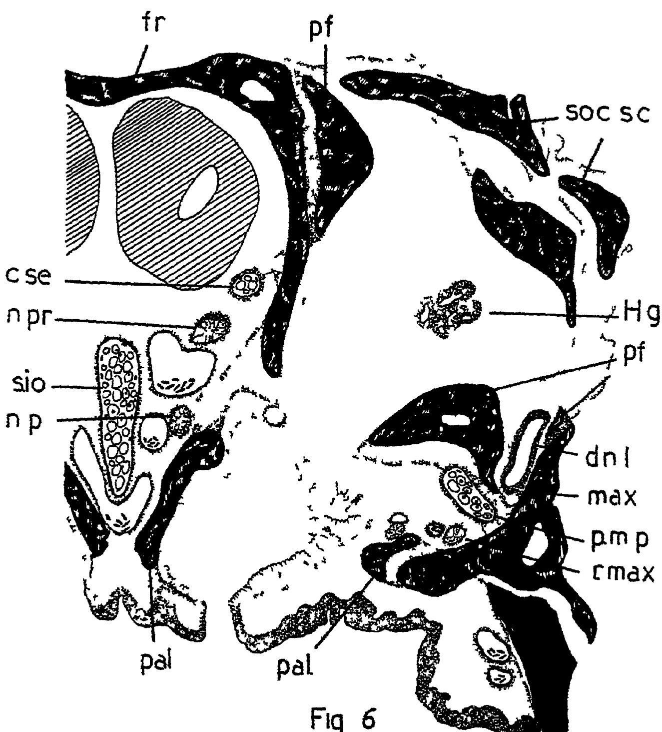
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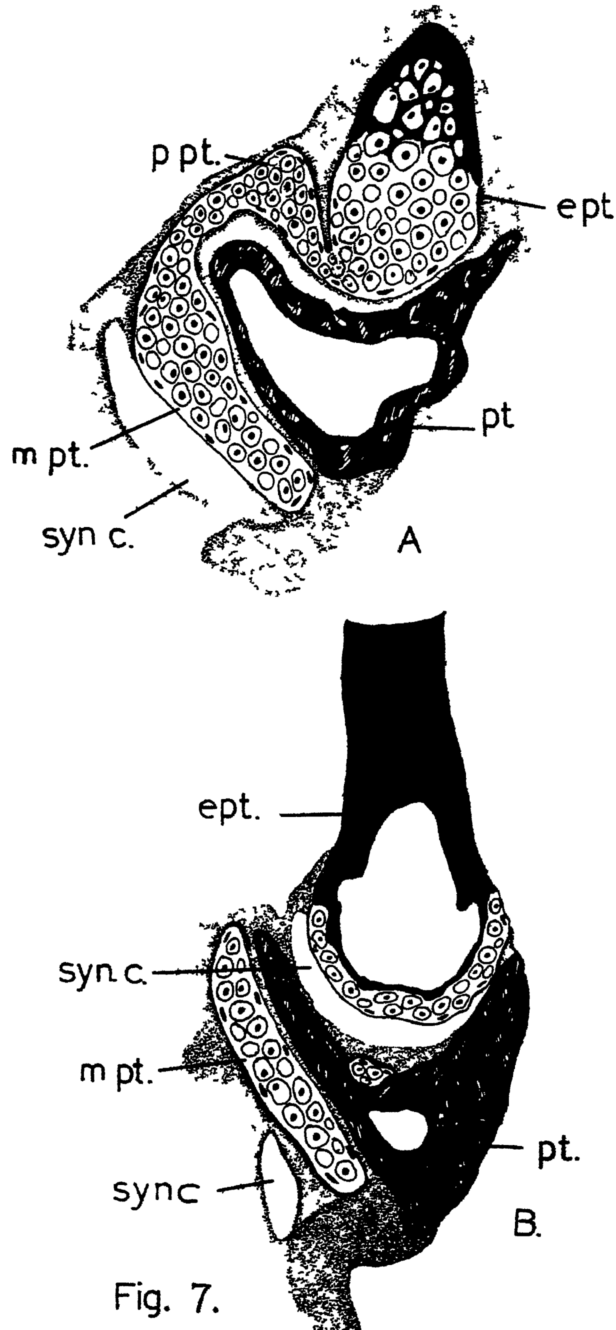

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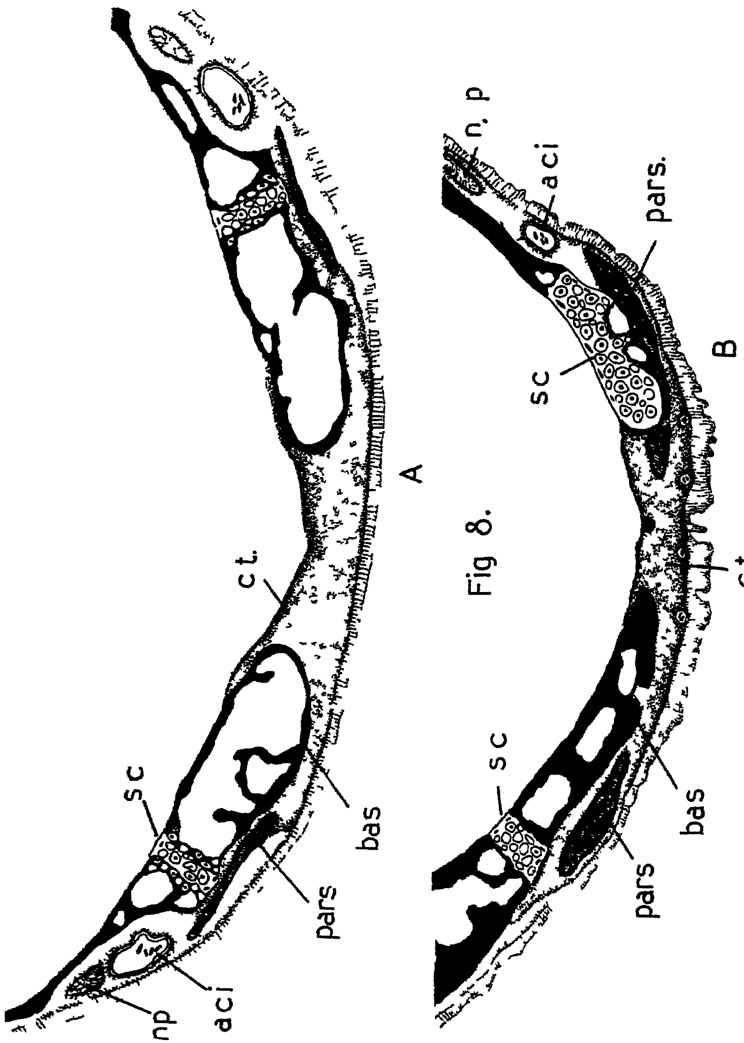

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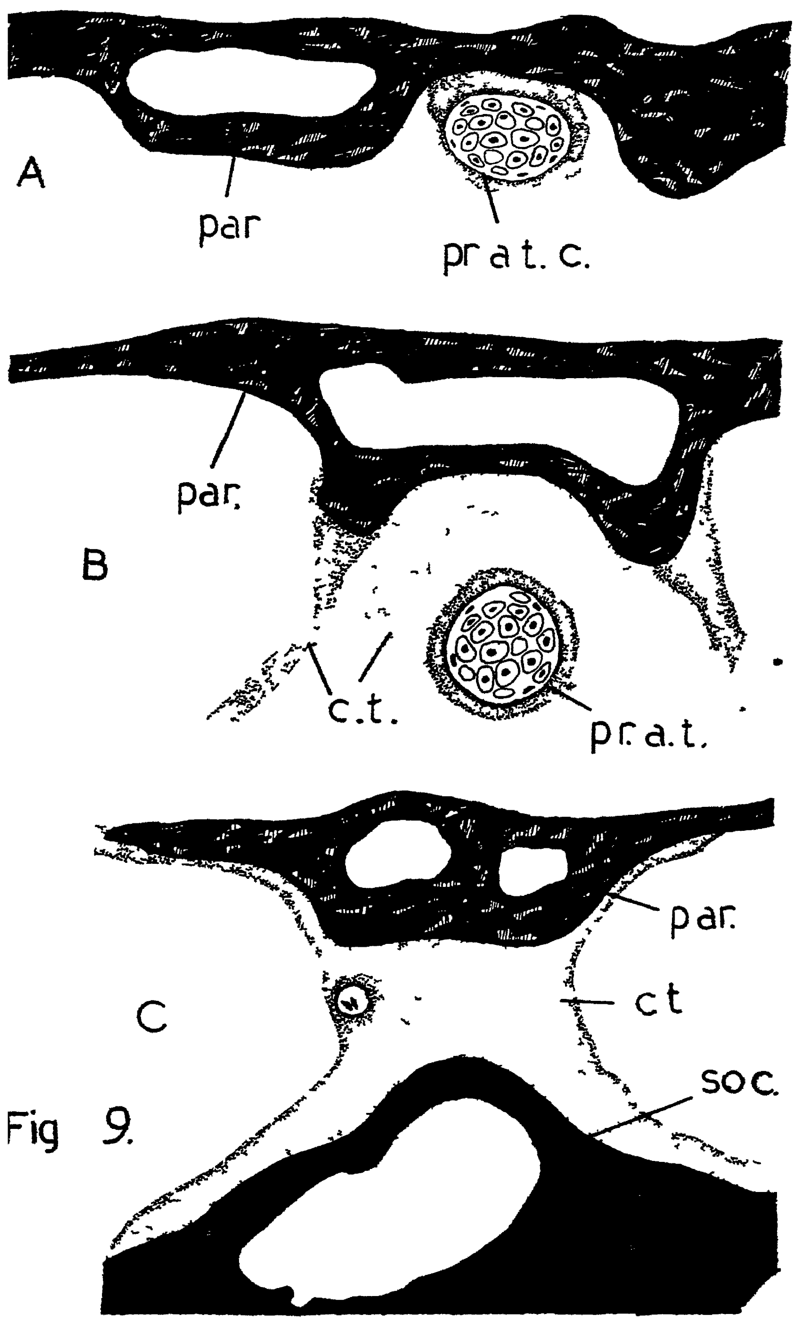

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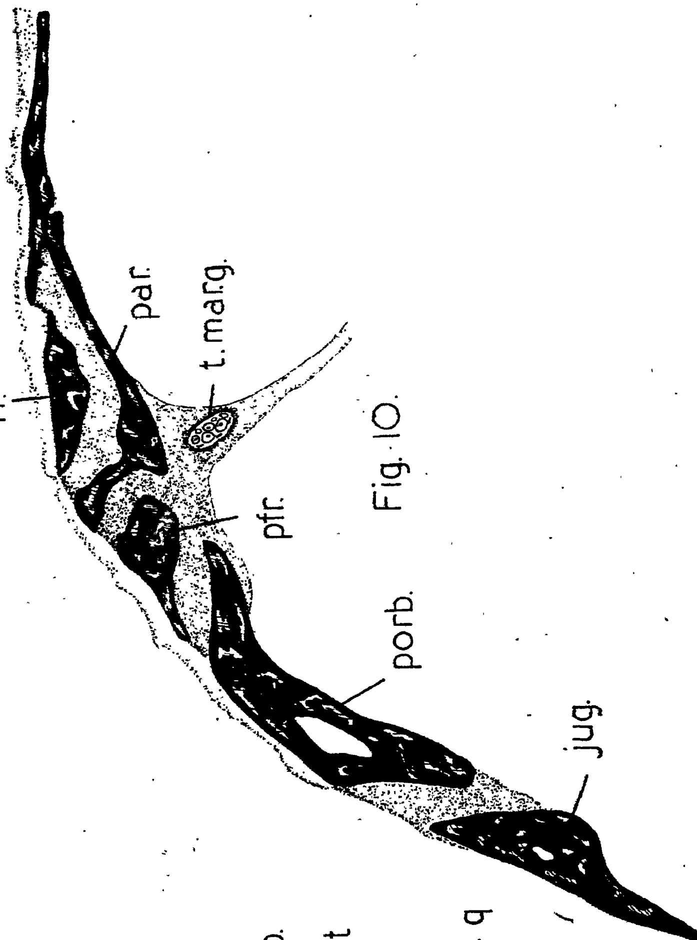

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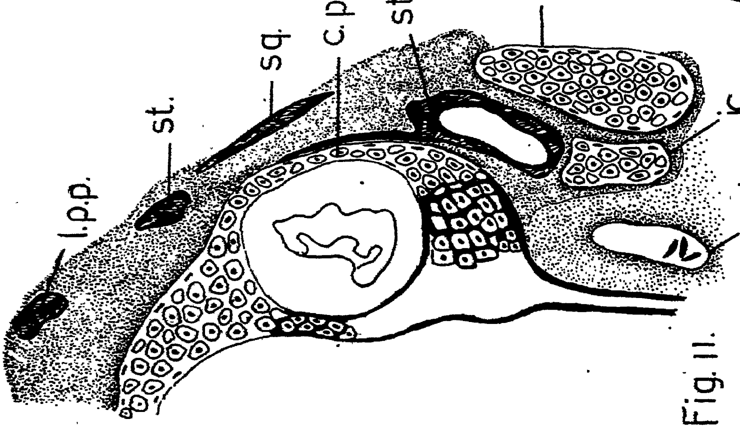

Fig. 11.

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LATENT INFECTIONS

BY

E. M. Robinson,
Onderstepoort.

Read 4th July, 1944.

In the realm of infectious disease produced by bacterial agencies, latent infection has been recognised since the days of Robert Koch, the term being used for symptomless infection following recovery from a disease. " Abortive " cases of disease have also been described where the infective agent has not multiplied very actively and either produced a very feeble reaction or one that may have passed unnoticed. Under latent infection may be classified that great variety of " carrier " conditions now recognised in infectious disease, of which the best known is that seen in typhoid fever of man. Charles Nicolle, one of the best known investigators of human typhus, has introduced a term " symptomless infection " or " infection inapparente." This refers to a condition in guinea pigs inoculated with typhus infection, when multiplication of the organisms occurs to the same extent as in others showing symptoms, but the animals do not show evidence of infection. This inapparent infection can be produced in guinea pigs by inoculation with typhus organisms and treating them with immune serum at the same time. Multiplication of the organisms occurs to the same extent as in guinea pigs which show symptoms as a result of infection with the organisms alone.

The term symptomless infection or " infection inapparente " should be reserved for those diseases in which the virus is distributed with respect to location, time and quantity in a manner characteristic for the usual course without, however, causing the appearance of clinical and anatomical signs of disease.

It is probable that the world is full of infectious agents which usually produce symptomless infection.

There is a type of infection occurring in both man and domesticated animals in which bacteria enter the body and remain in what should be described as a " resting " stage They may never multiply and cause symptoms, but under certain conditions may develop and cause active disease. One of the best examples occurs in tetanus infection in man, but there are examples in veterinary medicine as well. It has been shown that if tetanus spores washed free from toxin and thus rendered harmless, are inoculated into guinea pigs, tetanus

may subsequently develop in the animals if any necrotic process develops in them or they suffer from some bacterial infection. In man it has several times been observed that when tetanus or gas gangrene spores are introduced into the tissues by injuries such as gunshot wounds, they may not develop but remain alive in a latent or resting form. Months or years later if some agency stirs them into activity, as for instance an operation in their neighbourhood which involves them, fatal tetanus or gas gangrene may result. It is probable that the spores do not vegetate and produce toxin when introduced because the normal positive oxygen tension of the healthy tissues is sufficient to prevent germination. There must, however, be some factor which prevents their development immediately after the wound occurs, possibly phagocytosis or the chance absence of other bacteria which would help to produce the necessary anaerobic conditions for the development of the organisms.

In veterinary medicine there is a very good example of a resting infection, in a disease condition known as "Black Disease" in sheep, occurring in Australia and New Zealand. In certain areas in these countries sheep become infected in their tissues by an anaerobic bacterium known as Clostridium oedematiens, which gains access to the body with the food. It is estimated that 10 per cent. of the sheep in these areas harbour the spores of the organism in their livers. If such sheep are exposed to infestation with liver flukes the previously completely inactive spores suddenly develop in the damaged liver tissue producing toxin. and causing "black disease" to develop. In the absence of liver fluke infestation no symptoms would ever have developed.

In the disease of cattle known as blackquarter, although it has not so far been proved experimentally, it is very probable that one is dealing with a "resting" infection which gains access to the tissue by ingestion and locates itself in the muscles of the quarters, subsequently being lighted into activity by some as yet unknown factor.

The question may be asked whether some of the well known diseases such as tuberculosis, brucella infection, diseases due to fungi or cocci and many similar conditions bear any relationship to the conditions just mentioned. The complete cessation of development of the organisms in these conditions has not been demonstrated. The term "quiescent" infection would be a more suitable one for these conditions as there is always a primary focus of infection even if it is difficult to find, and in it there may be slight growth. It is sometimes retarded or completely arrested though at any time rapid multiplication may take place.

In tuberculosis in man or domesticated animals no symptoms may be evident although there is an allergic state which can

be demonstrated by the inoculation of tuberculin. A focus of infection, sometimes very small, is present somewhere in the body with living bacilli, which may multiply to some extent. The focus may remain about the same size for years and may at some time or other extend and produce clinical tuberculosis or may ultimately die off.

In brucella infection in cattle it is usually only in the later stages that one may see absolutely normal calving, without some degree of retention of the placenta. It frequently happens in this infection that calving is normal from the commencement and that at no time does actual abortion or the production of a weak calf occur.

In mastitis infection of cattle caused by Streptococcus agalactiae it is well known that infection of the udder may persist for long periods without any changes being observed in the udder or the milk, and certain workers on the disease suggest that a latent infection of a slight degree may exist in a high percentage of dairy cows. The existence of " carriers " of infections has been demonstrated in certain diseases in domesticated animals and birds, in which an infection persists without any clinical symptoms, either after an acute attack or without any clinical manifestations of infection ever having been shown. The best example of such an infection is that known as bacillary white diarrhoea in chickens. In this disease chickens may survive the early infection and the hens may retain an infection in the ovary in adult life. This ovarian infection may occur as well if infection is picked up after the early period of life, and the bird may become a carrier without ever having shown symptoms. It should, in fairness, be stated that hens with ovarian infection do not lay the normal number of eggs as a rule and may lay few or none.

A number of conditions have been recently described as " symbioses," where infective agents are found on the numerous membranes or in the blood without diseases symptoms being produced. As example one may quote pneumococci Clostridium welchii and Diphtheria bacilli in man. In animals examples are Pasteurella pestis in rats, fowl cholera bacilli in chickens, Trypanosoma lewisi in rats, and Brucella melitensis in goats. In insects one may quote malaria parasites in mosquitoes, trypanosomes in tsetse flies and many other examples.

It is certain that pathological changes do result sometimes with these so called " symbionts," and it is well known that the rickettsia of human typhus kills the louse in which it develops. The term " supragliscence " has been coined for the development of pathogenic bacteria on mucous membranes, living as commensals and not producing symptoms. The term " symbiont " may not be justified as it has not been proved that the host derives any benefit from the association.

Obviously the less severe the disease the more likely the organisms are to survive and a condition called herpes exists in man in which a type of hereditary infection occurs which ultimately results in a life long infection without symptoms. A true symbiosis occurs in termites where there is a bacterial infection of the intestinal tract by organisms which live on the cellulose eaten by the insect which in turn derives its protein from the dead bodies of the organisms.

An even better example is the digestion of cellulose in the rumen of cattle by harmless bacteria with the production of substances valuable for the nutrition of the animal.

Latency in certain diseases may exist during the incubation period, as a sequel to them, or as an intermediary stage. Incubationary or precocious carriers are seen sometimes in human typhoid, diphtheria and in Brucella infections. Carriers after the acute stage of the disease has subsided are very well known and may continue to be dangerous for years, but may go on to complete recovery. Latency in the intermediate stage is seen where infectivity persists in periods of apparent normality between acute attacks of certain diseases.

There are a number of latent bacterial and virus conditions in laboratory animals which may become active when experiments are carried out on them and this may complicate the experimental work.

It is certain that infectiousness and pathogenicity are relative conditions not dependent on the infectious agent alone but more so on the host with its various characteristics. Latency is probably mainly dependent on the host. The possession of antitoxins and other antibodies against certain diseases and the previous experience of the disease or some infections of similar etiology may play a part. Latency is particularly common in diseases where the mononuclear phagocytes play an important role in combating them. Genetic factors may play a bigger role than has previously been suspected, and the selection of resistant generations has undoubtedly occurred.

In conclusion it may be stated that the study of the true "inapparent" infection will probably be the key to a true understanding of the infectious agent-host relationship which results in latency of the organism.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XLI, pp. 273-280, February, 1945.*

THE EFFECTS OF VITAMIN C DEFICIENCY ON THE GUINEA PIG PANCREAS

BY

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With 3 Text Figures.

Read 4th July, 1944.

INTRODUCTION.

The effects of nutritional deficiencies in animals have been assessed largely by the weight and clinical appearance of the animal and by the gross macroscopical pictures seen post mortem. In recent years there has been a tendency to subject the tissues of such deficient animals to gross histological examination. However, little attention has been devoted to those subtle reactions in the cell which can only be demonstrated by refined cytological methods.

Very granular, deep staining cells known as Mankowski cells are frequently encountered in the pancreas of guinea pigs. Apart from Bensley's work the origin and nature of these cells have received little attention. According to Opie (1932), Bensley is said to regard these cells as abnormal acinar elements, arising in diseased pancreas of guinea pigs and caused by lack of green food. It is known that guinea pigs are extremely susceptible to a lack of Vitamin C in the diet, and it was felt that by producing scurvy in guinea pigs it might be possible to obtain some further information concerning the factors responsible for the appearance of Mankowski cells in the pancreas. Moreover, despite the fact that scurvy has been extensively studied in guinea pigs from time to time, the literature available provides no data concerning the cytological changes in pancreatic cells in Vitamin C deficient guinea pigs.

Bessey, Menten and King (1934) in discussing the pathological changes in the organs of scorbutic guinea pigs, noted that in the islets of Langerhans occasional cells show hydropic degeneration.

Although it will be shown in this paper that the number of Mankowski cells is not consistently increased in scorbutic guinea pigs, the secretory activity of the acinar tissue is, however, definitely impaired.

Material and Methods.

Twenty-one young guinea pigs, whose initial weights were between 90 and 260 grams, were used. The length of time which these animals were subjected to the Vitamin C deficient diet varied from 13 to 45 days. Those animals which lived for longer than 35 days were receiving subminimal doses of Vitamin C.

The diet consisted of 45 per cent. bran, 30 per cent. dried skim milk, 25 per cent. crushed oats and 2 per cent. salt. These constituents were mixed with water and the animals liberally supplied with the mixture. In addition to the food, 1 cc. cod liver oil was administered twice weekly to each animal.

The guinea pigs were weighed daily and were killed by a blow on the head when they showed signs of weakness and possible Vitamin C deficiency. In many cases they were found in a collapsed condition or in convulsions just prior to death. Post mortem findings were fairly consistent: the animals were thin and had lost a good deal of weight after gaining for about two weeks. There were haemorrhages into the joints and in the muscles around them, in the bladder, and in the gums. The bones were soft. The gall bladder was often distended, the spleen small and brick-coloured, and the supra-renals large and congested. The pancreas was occasionally slightly congested but there was never any abnormal condition which could be seen macroscopically.

The pancreas of each animal was removed immediately after death, and fixed in the following fluids:

Cobalt nitrate and formalin for da Fano's technique.

Zenker formol or Regaud acetic, and

Formalin 10 per cent.

After dehydration and embedding, sections were cut at 3 microns thickness, and stained with Mallory's triple stain Altmann's Aniline Acid Fuchsin and Methyl Green, and Haematoxylin and Eosin.

Observations.

This investigation comprises histological and cytological studies on the acinar and islet cells of twenty-one guinea pig pancreases. The experimental animals are divided into three groups, depending on the length of time they were on the diet, viz.:

Group I, 7 animals treated for 13 to 21 days

Group II, 11 animals treated for 22 to 35 days.

Group III, 3 animals treated for 36 to 45 days.

A brief description of the state of each pancreas has been given in Tables I, II and III, and the more important points arising from these are described and discussed.

GROUP I—13 TO 21 DAYS.

Guinea Pig Number ...	56	2	17	52	1	47	51
Number of Days ...	13	17	19	19	20	21	21
Vascularity of Tissue	Good	Very vascular	Good	Good	Fair	Good	Good
Secretory Activity of Acinar Cells	Some agranular cells. Many fully granulated. Others katabolic and early anabolic	Fair number of agranular cells. Others mainly late anabolic, early katabolic and fully granulated	Some agranular and early anabolic cells. Many fully granulated, early and late katabolic cells	Fairly numerous agranular cells. A few early anabolic and others in all stages of katabolism	Many agranular cells others fully granulated, late anabolic and early katabolic	Many agranular cells. Others early anabolic and late katabolic	Many agranular cells, some early anabolic and all stages of katabolism
Mankowski Cells ...	None	A fair number. Most are degranulating. Others are anabolic and fully granulated	None	None	None	None	Fairly large number. Mainly anabolic cells
Mitochondria	Numerous in agranular cells. Fewer in other cells. Often coarse structures	Numerous. Many are coarse	Numerous. Fine structures	Numerous in agranular cells. Fewer in other cells. Often coarse structures	Numerous. Often coarse structures	Not seen (due to fixation)	Quite numerous. Fine structures
Golgi Apparatus ...	Not seen (due to fixation)	Medium-sized reticulum	Small reticulum. Threads not always joined	Small to medium sized reticulum	Medium sized reticulum	Not seen (due to fixation	Small to medium sized reticulum
Nuclear Structure ...	Vesicular	Vesicular	Vesicular	Vesicular	Many vesicular. Some agranular cells have chromatic nuclei	Vesicular	Vesicular
Cytoplasm	Homogeneous	Homogeneous	Homogeneous	Mainly homogeneous, but shreddy in some cells	Homogeneous	Homogeneous	Homogeneous
Islets of Langerhans	Vascularity good. a-cells have few granules. b-cells granular	Capillaries dilated. a-cells in early stages of degranulation. b-cells granular	Vascularity fair. a-cells numerous and granular. b-cells not fully granulated	Capillaries dilated. a-cells fully granulated. b-cells half full	Vascularity fair. a-cells degranulating. b-cells granular. Some C-cells	Capillaries dilated a- and b-cells granular	Vascularity fair. A few granular a-cells. b-cells granular. Numerous small islets.

GROUP II—22 TO 35 DAYS.

Guinea Pig Number ...	14	18	27	4	13
Number of Days ..	22	22	23	25	26
Vascularity of Tissue	Good	Fairly congested	Capillaries dilated	Good	Good
Secretory Activity of Acinar Cells	Numerous agranular cells. Others early anabolic and late katabolic	Mostly agranular cells. Others early anabolic and late katabolic	Quite numerous fully granulated cells. Some agranular Others are all in between stages	Numerous agranular cells. Some being vacuolated. Others early anabolic and very late katabolic. 20 80 cells are granulated	Fewer agranular cells. Some anabolic. Many fully granulated and early katabolic cells
Mankowski Cells ...	None	A few katabolic cells	None	None	None
Mitochondria	Numerous. Fine structures	Numerous. Fine structures	Quite numerous. Fairly coarse small structures	Very numerous, especially around nuclei. Some are coarse and vacuolated	Fairly numerous in agranular cells. Small fine rods
Golgi Apparatus ..	Medium to large sized reticulum. Sometimes granular	Small to large reticulum. Fine threads	Not seen (due to fixation)	Not seen (due to fixation)	Medium sized reticulum.
Nuclear Structure ...	Vesicular	Vesicular. Large nucleoli	Vesicular	Slightly chromatic	Vesicular
Cytoplasm	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous
Islets of Langerhans	Vascularity good. a-cells fairly numerous and granular. b-cells not fully granulated	Vascularity fair. a-cells degranulated. b-cells granulated	Capillaries dilated. a-cells granulating. b-cells granular. One or two C-cells	Vascularity fair. a-cells degranulating. b-cells granulating	Vascularity good. a-cells numerous. Granulating and late degranulating cells. b-cells in the same stages. A few c-cells seen

GROUP II—22 TO 35 DAYS—(continued).

Guinea Pig Number ...	22	53	54	39	31	35
Number of Days ...	27	27	27	28	31	35
Vascularity of Tissue	Good	Good	Good	Good	Good	Good. Large vessels dilated
Secretory Activity of Acinar Cells	Numerous agranular cells. Fairly numerous later katabolic cells	Many cells agranular. Others early anabolic and late katabolic	Fairly numerous agranular cells. Others late anabolic and early and late katabolic	Many agranular cells. Others early anabolic and late katabolic	Many agranular cells. Equal numbers of early anabolic and late katabolic cells	Many agranular cells. Equal numbers of early anabolic and late katabolic cells
Mankowski Cells ...	A few storage cells. Many anabolic, fully granulated and katabolic cells	None	None	Very few	Numerous. Many anabolic and fully granulated cells	Fairly numerous
Mitochondria	Exceptionally numerous. Filaments and short, coarse rods	Numerous fine mitochondria	Mainly fine, but in some agranular cells they are coarse	Numerous fine mitochondria	Numerous fine mitochondria	Numerous small mitochondria
Golgi Apparatus ...	Medium to large sized reticulum of fine threads.	Medium sized reticulum	Small to medium reticulum	Small reticulum	Fairly large, loose reticulum	Medium sized reticulum
Nuclear Structure ...	Vesicular and fairly small	Vesicular	Vesicular	Vesicular	Vesicular	Vesicular
Cytoplasm	Homogeneous and clear	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous
Islets of Langerhans	Capillaries dilated. a- and b-cells granulating	Capillaries dilated. a-cells in early degranulation. b-cells granulating. Many small islets	Capillaries dilated. a-cells degranulating. b-cells granular	Vascularity fair. a- and b-cells granulated. Many small islets	Vascularity fair. a- and b-cells have few granules (Bad fixation)	Vascularity fair. Quite numerous a-cells, some starting to degranulate. b-cells granular

GROUP III—36 TO 45 DAYS.

Guinea Pig Number .	26	23	25
Number of Days ...	11	45	45
Vascularity of Tissue	Good. Capillaries dilated	Slightly congested	Fair
Secretory Activity of Acinar Cells	Most of the cells are agranular. Others are early anabolic and late katabolic	Numerous agranular cells. Others are early anabolic and late katabolic. Very few granules in the cells	Numerous agranular cells. Others early anabolic and late katabolic
Mankowski Cells ...	Very few cells seen	Quite numerous. Many degenerating storage cells. Cells in all stages of the secretory cycle	Numerous. Many degenerating storage cells. Cells in all stages of the cycle
Mitochondria	Numerous. Many fine filament	Numerous. Some are coarse	Numerous. Fine structures
Golgi Apparatus ...	Medium sized reticulum	Small to medium sized reticulum	Medium to large sized reticulum
Nuclear Structure ...	Vesicular	Vesicular	Vesicular in most cells. Sometimes slightly chromatic
Cytoplasm	Homogeneous	Homogeneous	Homogeneous
Islets of Langerhans	Capillaries dilated. a-cells granulated. b-cells contain fewer granules	Capillaries dilated. a- and b-cells are granulated	Fairly vascular. a- and b-cells both contain granules, but some cells are degranulating

Group I (13 to 21 days).—Superficial examination of the pancreas of the seven animals in this group showed no abnormalities. The connective tissue, blood vascular supply and duct system were within the range of normality.

Zymogen cells were seen in all stages of the secretory cycle, a fairly large number being fully-granulated, and the remainder in stages from agranulation to late katabolism. There were, however, individual variations in the different animals. Mankowski cells were found in two animals (2 and 51), being fairly numerous in No. 51. The mitochondria are numerous in most cells, the number varying inversely with the number of zymogen granules. Three types of mitochondria were found—long, thin filaments, short, thicker rods and granules. The filamentous type was usually the most predominant, but in some cells the granular and rod-like forms were more common. Certain changes were noted in the structure of some mitochondria which appeared to be thickened and swollen. These thickened mitochondria were seen in some of the acinar cells of guinea pigs 1, 2, 52 and 56.

The Golgi apparatus was apparently unaffected. It appeared as a small to medium-sized reticulum of fine threads. The size varied according to the stage of the secretory cycle of the cells. The nuclei were vesicular and had prominent nucleoli.

The cytoplasm was homogeneous and pale-staining in all animals except No. 52. In the pancreas of this animal a number of agranular cells, lying singly among the acini, appeared to have increased in size. The cells were oval in shape and the cytoplasm had a shreddy consistency and had shrunk away from the cell membrane. The nuclei were hypochromatic, the mitochondria thickened and the Golgi apparatus fragmented. These were the only abnormal cells seen.

The islets of Langerhans were normal. The vascularity was within normal limits and the alpha and beta cells were seen granulating and degranulating. There were numerous small islets in guinea pigs 2 and 51.

Group II (22 to 35 days).—In the eleven guinea pigs of this group the pancreas was morphologically normal as far as the connective tissues and blood vessels are concerned. The feature noticed first, however, was the relative scarcity of zymogen granules in the acinar cells. In nine of the animals there were many agranular cells and a large number of cells in early anabolism and late katabolism. Nos. 27 and 13 had fully-granulated cells and cells in all stages of the secretory cycle. Mankowski cells were present in guinea pigs 18, 22, 39, 34 and 35. These cells were all normal in structure.

In the cells of this group too, the mitochondria exhibited structural changes; they were numerous in all the cells, but in Nos. 4 and 22 exceptionally so. The structural changes noted

were as follows—the long, thin filaments tended to break up into shorter rods and granules which accumulated around the nucleus. They often had a coarse structure. A further abnormality was that the mitochondria might become vacuolated. (Fig. 1a.)

The Golgi apparatus was apparently not affected to any extent. The structure was reticular and the size varied from small to large. The nuclear and cytoplasmic structure were normal.

In a small area of the pancreas of guinea pig 4 there was vacuolation of the acinar cells. The vacuolation began among the zymogen granules, and continued until only two or three granules remained. Eventually there was only a thin rim of cytoplasm around the cell membrane, though a few mitochondria might remain in the cytoplasm. As the vacuolation proceeds the nucleus is flattened against the base of the cell, but although the shape is changed, it remains vesicular. This probably indicates that the cell is filling up with fluid. All or some of the cells of an acinus may be vacuolated (see Fig. 1b), but the vacuolation is not of the same type as that seen in rats fed with mealie meal and sour milk, in which the cells appear to metaplase and become flattened and " duct-like."

Another feature of the pancreas of guinea pig 4 is the very small number of cells containing zymogen granules. Approximately only twenty cells per field of eighty have granules, and these cells are either very late katabolic or early anabolic.

In this group too the islets of Langerhans are apparently normal, as regards morphology and cell structure. The cells are in different stages of the secretory cycle.

Group III (36 to 45 days).—The three animals in this group were given a daily subminimal dose of Vitamin C, which is probably the reason for the length of time they survived.

In all three cases the agranular type of cell and cells with few granules were fairly numerous. A few Mankowski cells were seen in No. 26, and large numbers in guinea pigs 23 and 25. The pancreas of guinea pig 26 was, on the whole, very similar to those described in Group II.

The mitochondria in the cells of No. 23 were very numerous. Filaments, rods and granules were found; the granular type were sometimes thickened. The Golgi apparatus in this animal was a small or medium-sized reticulum.

No. 25 also had numerous mitochondria of the same structure as those in No. 23, although the filamentous type was the most common variety. The Golgi apparatus varied between medium and large size—in some cells it was so large as almost to fill the cell.

The most striking feature about the pancreatic tissue of these two animals was the large number of degenerating

Mankowski cells. This degeneration occurred in cells in a storage phase, and although No. 25 contained cells in all stages of the secretory cycle it was never observed in the earlier phases.

The Mankowski cell arises from the katabolic zymogen cell. The fine granules which typify the cell appeared first in the basal area around the nucleus. As the cell fills with granules and the zymogen granules are excreted, the mitochondria decrease in number The nucleus at this stage is slightly more chromatic and the nucleoli are prominent. The Golgi apparatus, although still reticular, becomes reduced in size. (Fig. 2a.)

In the fully-granulated pre-storage phase there are few or no mitochondria. The cell is filled with closely packed granules, and the fairly chromatic nucleus lies almost basally. The Golgi apparatus is a compact structure near the nucleus. In the storage cell the Golgi apparatus is so dense that the threads of the reticulum cannot be seen, and the granules present an almost homogeneous appearance. It is these cells that degenerate. (Fig. 2b.)

Degeneration proceeds in the following manner: vacuoles appear in the midst of the granules. At first there is one small vacuole, then two or three are formed. These coalesce into one large vacuole which may almost fill the cell. As the vacuole enlarges the granules disappear, probably by liquefaction. Those granules that may remain surround the vacuole and a few are seen to stretch in threads across it. The cell enlarges, often to three or four times its original size, and the surrounding cells are pushed outwards and change their shape. While the vacuole is forming the nucleus becomes hyperchromatic and lies peripherally, as does the Golgi apparatus which later fragments and finally disappears. (See Figs. 3a. to 3d.)

In the very late stages only a few threads of cytoplasm are seen running across the large spherical vacuole which may even be devoid of all cytoplasmic structures. Some Mankowski cells exhibit fragmentation of the Golgi apparatus before vacuoles appear, but this is not a common occurrence.

The islets of Langerhans are normal, and no signs of degeneration are noted in the cells.

Discussion.

In the scorbutic guinea pig there is macroscopically no change in the pancreas, but histological changes have been noted.

As stated above, the Mankowski cell is formed by granulation from a degranulating zymogen cell. Although many of the zymogen cells in the pancreatic tissue of these animals are degranulating, the Mankowski cells were present in only

ten animals. It is evident, therefore, that Vitamin C deficiency does not cause an increase in the number of Mankowski cells. It is probable that Vitamin C may not have been lacking in the diet which Bensley fed to his animals, and another factor may have been responsible for the numerous Mankowski cells found by him.

In two animals, however, the number of Mankowski cells was large. Most of the cells were in a storage phase and many of them were vacuolated and degenerating. The vacuolation could be traced from its earliest stages to the complete destruction of the cell. (Fig 3d.) Although apparently filled with a fluid substance, the cells were not regarded as being in a state of hydropic degeneration.

A most important feature in the pancreatic tissue of these animals is the depletion of zymogen granules in the acinar cells. This was found in 14 of the 21 experimental animals. It was less consistent in those animals which were on diet for 13 to 21 days, being observed in 3 of the 7 animals. These animals had fairly numerous cells without granules and the remaining cells had relatively few zymogen granules. The number of cells without granules apparently increased with the length of duration of the C deficiency, for of the 14 guinea pigs which were chronically deficient, having been on diet for periods of 22 to 45 days, 11 were affected in the same way. In the latter animals, however, the depletion was even more marked. and in one case only 25 per cent. of the cells of the pancreas had any granules, and then very few in each cell. In most cases approximately 50 per cent. of cells had no granules, and the remainder were in stages of very early anabolism or late katabolism.

This is a significant point, and shows that chronic Vitamin C deficiency must seriously interfere with the formation of secretory granules. Many of the animals had been starved for 15 hours before being killed, and all had eaten very little food for two or three days before death. We know that under these conditions the cells should be filled with secretory granules.

Gillman (1939) states that there are three conditions necessary for gland secretion in cells which have a granular precursor of the secretion, namely, the elaboration of secretory granules; the storage of the granules until a stimulus to excrete them reaches the cell, the stimulus being either chemical or nervous; and the extrusion of granules from the cell. It is known that cells do not form new granules until all those of the previous cycle have been excreted. In the experimental animals, therefore, when the cells have liberated their accumulated zymogen granules they should immediately commence to elaborate fresh zymogen granules. However, the lack of Vitamin C apparently interferes with the formation of granules.

Hence, in severe cases, the acinar cells are depleted of granules without any evidence of new ones being formed.

Apart from this lack of granule formation in these animals there are no other cytologically recognised changes in the acinar cells, except that in many cells the characteristic, thin, filamentous mitochondria are replaced by short coarse rodlets and granules which are often vacuolated. (See Fig 1a.)

The islets of Langerhans exhibit the least changes. They are indistinguishable from the normal in most cases, although in one or two animals the number appears to have increased. The cells of the islets do not show any noticeable deviation from the normal even with refined cytological methods.

Bessey, Menten and King (1934) state that the presence of occasional hydropic degeneration in the islets of scorbutic guinea pigs was probably only an indication of spontaneous intestinal infection. Sigal and King (1936) demonstrated that with Vitamin C depletion there is a rise in fasting blood sugar and a lowered glucose tolerance. This, however, may be due to metabolic disturbances in other organs, possibly the liver

Summary.

1 The pancreatic tissue of 21 guinea pigs fed on Vitamin C deficient diet for periods varying between 13 and 45 days has been described.

2. The number of Mankowski cells in the pancreas is not related to the presence or absence of Vitamin C.

3. The Mankowski cells are derivatives of the acinar cells, and in two cases the cells were very vacuolated. The function of these cells has not been established.

4 The acinar tissue in chronically C deficient animals was noticeably affected, in that the cells fail to form zymogen granules even after 15 hours starvation.

5 Such lack of formation of granules is a constant feature in animals on diet for 21 to 45 days, being found in 11 animals out of 14. In animals on diet for 13 to 21 days it was found in 3 cases out of 7.

6. The islets of Langerhans show no significant cytologically recognised differences in scorbutic guinea pigs.

7. It would appear from this that Vitamin C deficiency in guinea pigs interferes with pancreatic activity by inhibiting the formation of secretory granules in the acinar cells of the pancreas.

I wish to thank Professor R. A. Dart, in whose department this work was carried out. To Dr. Joseph Gillman I am indebted for his invaluable advice and criticism.

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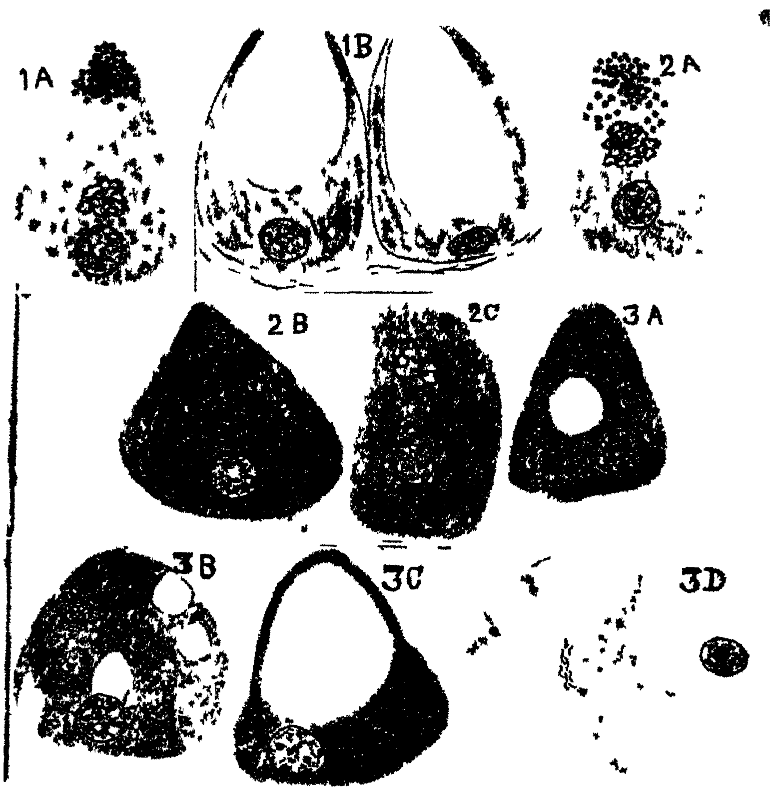
INDEX TO ILLUSTRATIONS

Fig. 1A: Acinar cell showing zymogen granules, Golgi apparatus and mitochondria.

Fig. 1B: Vacuolated acinar cells, seen in Guinea Pig No. 4.

Figs. 2A, 2B, 2C: Stages in the secretory cycle of the Mankowski cell. 2C is a katabolic cell.

Figs. 3A, 3B, 3C, 3D: Stages of vacuolation of the Mankowski cell.



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THE VOLUME OF THE VARIOUS SUBDIVISIONS OF THE HUMAN PITUITARY UP TO THE AGE OF 14 YEARS

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With 1 Text Figure.

Read 4th July, 1944.

Although a great deal of work has recently been done on the morphology of the human pituitary, our information regarding the weight and volume of the pituitary from birth to puberty is still incomplete.

Rasmussen (1938) gives the weight of the pituitary at birth as about 100 mg. and notes a fairly rapid increase in weight in early childhood. This growth gradually slows down as adulthood is attained. He further states: " No very detailed curve of growth is available for this period."

Covell (1927), studying the prenatal hypophysis, found exceedingly rapid growth in early prenatal life. The pars anterior forms a greater portion of the gland in the earlier periods of development than it does later. In this respect, the pars intermedia resembles the pars anterior, whereas the pars nervosa forms a smaller portion of the gland in its early foetal development than it does at birth. At full term the pars anterior forms 78 per cent. of the gland, the pars intermedia 2 per cent., and the pars nervosa 20 per cent.

Rasmussen (1928 and 1934) gives an account of the principle components of the hypophysis of the normal adult male and female. In an analysis of the components of 111 cases of males, 93 cases of non-pregnant females, 24 cases of pregnant females, he found that the pars anterior formed 78·4 per cent., 80·5 per cent. and 84·1 per cent. respectively. The pars nervosa formed 23·1 per cent. in males, 18·0 per cent. in non-pregnant females, and 15·0 per cent. in pregnant females. The pars intermedia in males is 2·1 per cent. of the whole gland; in non-pregnant females it is 1·5 per cent., and in pregnant females 0·9 per cent. He gives no account, however, of the weight or volume of the pituitary gland from birth to 15 years.

This paper is a record of volumetric estimations of 18 human pituitaries from birth to puberty. While the material is still inadequate to provide an accurate picture of the differential growth of the parts of the pituitary, nevertheless the pituitaries

available are sufficiently evenly distributed between the two periods to afford a good indication of the general trend of development.

Nomenclature.—In this investigation the term pars anterior includes the anterior lobe and the pars tuberalis. The measurement of the pars nervosa includes in most cases a portion of the infundibulum or stalk. The pars intermedia includes the residual cleft of Rathke's pouch and the basophil cells bordering the pars nervosa.

Material.—The glands were obtained from Europeans and South African Negroes of both sexes. No attempt has been made to separate the material into different categories according to racial origin, although it was found that the pituitary glands of American Negroes are larger than that of Europeans. (Pearl, Gooch and Freeman, 1935, cited by Rasmussen, 1938.)

The specimens were fixed in formol, dehydrated and embedded in paraffin wax. They were then serially sectioned horizontally, at ten microns. Every tenth section was mounted and stained with Ehrlich's haematoxylin and eosin.

Method.—A modification of Rasmussen's method (1922) for volumetric determination was used. Rasmussen projected every twentieth section (ten microns thick and stained with haematoxylin and eosin) on heavy paper of uniform thickness at a surface area magnification of 400. The areas of the various parts were cut out and weighed, the proportion of any one part of the whole gland thus being determined and converted into milligrams.

Rasmussen also states that as the shrinkage due to fixation and dehydration is only 1 per cent. more in the pars anterior than in the pars posterior, it can be disregarded.

The material for this investigation was treated in a similar way except that every tenth section was projected on to ordinary paper and then the area of the various parts was measured with a planimeter. The volume of each part was then determined in the following way:—

if x *sq.* mms. be the area measured (Magn. 20 diams.)

Then the actual area is $\dfrac{x}{400}$ sq. mms.

Each section was ten microns thick and every tenth section was projected.

Therefore the "depth" of every section measured is 10 x 10 microns; that is 0·1 mm.

The volume of every section is then $\dfrac{x}{400}$ (0·1 cmm.).

All the volumes thus calculated added together give the total volume of each part.

This method has certain advantages. The volumes of the various parts can be determined excluding the connective tissue capsule. Rasmussen states that if the dura mater is not properly removed from the gland there may be a difference in weight of 100-150 mgms. Volumetric estimations overcome this difficulty.

The pars anterior, pars nervosa and pars intermedia were each measured and their volumes determined. These together gave the volume of the whole gland, and the percentage of the different parts could be estimated. In all cases the pars tuberalis was included with the pars anterior and the infundibulum with the pars nervosa. Before dehydration the infundibulum was cut off close to the pars nervosa, the remaining portion being included in the measurement of the posterior lobe. The residual cleft was included in the estimation of the volume of the pars intermedia.

Analysis of Data.

In all, eighteen glands were measured. Of these, five were males and thirteen females. Owing to the small number of glands available it was decided to graph males and females together (Fig. 1). The data obtained by this investigation are presented in Tables 1 and 2.

From the graphs it will be seen that although there is a definite increase in the size of the pituitary from birth to fourteen years, growth does not occur proportionately with age. The volume of the whole gland increases from 30 cmm. at birth to 312 cmm. at the fourteenth year.

The gland of the 20-month-old child has a volume of 54 cmm., whereas the individual of 1 year 11 months has a gland of almost twice the volume, that is 90 cmm. The volume at 2½ years is, however, only 79 cmm., but at 3 years and 3½ years it is as much as 109 cmm. This is in part due to an enlargement of the pars intermedia at this age. This enlargement, however, does not altogether account for the great increase in the volume of the whole gland. At 4 years the volume obtained was 77 cmm., and from there on the whole gland increases in size according to age.

Relation of Pituitary Volume to Body Height and Weight.

Unfortunately the height and weight of all the individuals was not obtained. From the eleven cases studied it will be seen (Table 3) that there is a better correlation between the volume of the pituitary and body height. The factor $\frac{\text{volume}}{\text{height}}$ is far more constant than that of $\frac{\text{volume}}{\text{weight}}$. This agrees with the findings of Rasmussen, Roessle, Petersilie and Miyazaki (quoted by Rasmussen, 1938).

Graphs of Pars Anterior.

The curve plotted for the volumes of the pars anterior at different ages follows that of the whole gland very closely. This is to be expected, as the pars anterior forms the greatest part of the gland (63-88 per cent.). There is no drop in the volume of the pars anterior at 2½ years corresponding to the diminution in the volume of the whole gland at this age. The drop in total volume at this age is due to a decrease in the size of the pars nervosa.

A rapid increment in growth takes place between 20 months and 4 years. As four of the glands examined exhibited the same phenomenon it is hardly likely that this could be mere coincidence.

At birth the pars anterior forms 80-90 per cent. of the gland. There is then a relative decrease in its size at 3 years and 3½ years, when it forms only 66-68 per cent. of the volume of the pituitary. At 4 years it forms 80·3 per cent. of the total volume and at 10 years 67 per cent. From 10 years there is a relative increase in the size of the anterior lobe which continues until the age of 14 years, corresponding to the pre-pubertal period.

Graph of Pars Nervosa.

From the figure it can be seen that the pars nervosa grows more rapidly between birth and 4½ years than between 4½ years and puberty. At birth the volume is 40 cmm. and 60 cmm. at 14 years.

The relative volume of the pars nervosa varies from 9·22 per cent. to 35·71 per cent. At birth and shortly thereafter it forms a relatively small part of the gland, associated with the large pars anterior (forming 80-90 per cent. of the gland at this stage). There is then a steady increase in the relative size of the pars nervosa up to 2 years of age. This level is maintained up to 10 years of age, and then there is a relative increase up to 14 years corresponding to the pre-pubertal rise of the pars anterior.

Graph of Pars Intermedia.

The pars intermedia, according to Rasmussen (1928), is the most variable part of the pituitary. In this group of pituitaries, however, it does not vary very much. There is a steady increment in size with age. At 3 years and 3½ years there is, however, a definite increase in the size when it attains its maximum volume of 13·5 cmm. This volume is twelve times as large as that of the pars intermedia of 5-month-old pituitary (approx. 1·1 cmm.), and is six times as large as that of the two-year-old. According to the graph there is a drop at 5½ years, a rise to 9·83 cmm. at 11 years, and a further drop to 7·0 cmm. at 14 years.

The percentage of this portion of the gland varies from 1·2 per cent. to 13·0 per cent. There is a marked transient increase in the relative size of the pars intermedia round about 3 years of age when it forms about 13 per cent. of the gland.

Comment.

No conclusions can be drawn from these observations owing to the fact that in most cases only one observation was made for each group. It was observed, however, that the figures obtained fell well within the range of variation of the normal adult.

The relative size of the different subdivisions of the pituitary gland of the 11- and 14-year-old female do not differ greatly from the relative size of these parts in the adult non-pregnant female.

Age.	Pars Anterior. %	Pars Intermedia. %	Pars Nervosa. %
11 years	78·18	4·11	17·71
14 years	79·90	2·10	18·0
Adult ... ... (Rasmussen)	80·50	1·50	18·0

Summary.

The volume of the entire gland as well as that of each portion was studied in 18 human pituitaries of both sexes.

As a whole, the gland grows most actively between the ages of 10 and 14 years. The growth of the pars anterior follows very closely that of the whole gland. The pars nervosa forms a relatively small portion of the gland at birth, but grows steadily from birth to 4½ years and thereafter grows relatively slowly. The pars intermedia scarcely alters its size throughout the period except for a transient increase in volume at about 3 years.

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TABLE I—MALES

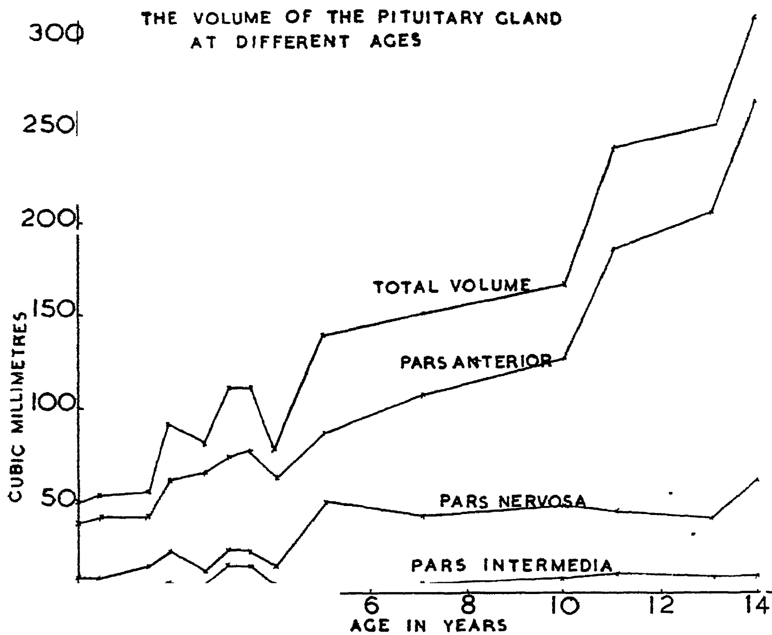
Age	Total vol. (cmm.) by calculation	Vol. of Ant. lobe (cmm.)	Vol. of Pars. Int. (cmm.)	Vol. of Post. lobe (cmm.)	Percentage of Parts		
					Ant. lobe	Pars. Int.	Post. lobe
8 months (premature)	32·065	22·26	1·215	8·59	69·42	3·79	26·79
Stillborn	43·26	38·14	1·13	3·99	88·17	2·61	9·22
5 months	52·725	42·515	1·1025	6·55	84·7	2·2	13·1
3½ years	109·165	74·675	13·645	20·845	68·41	12·50	19·09
13 years	252·57	204·61	8·06	40·9	81·0	3·0	16·0

TABLE II—FEMALES

Stillborn	62·032	48·365	1·525	12·1425	77·97	2·46	19·57
24 hours	68·69	57·92	2·45	8·32	84·32	3·57	12·11
20 months	54·44	40·35	1·27	12·78	73·9	2·4	23·6
1yr. 11ms.	89·687	61·97	4·895	22·822	69·0	5·0	26·0
2½ years	79·125	65·65	2·29	11·185	83·0	2·9	14·1
3 years	109·00	72·47	13·93	22·595	66·5	13·0	20·5
4 years	77·432	62·155	2·647	12·64	80·3	3·4	16·3
5½ years	138·127	87·880	1·675	48·572	63·62	1·21	35·17
7 years	150·24	106·95	4·39	38·89	71·19	2·92	25·89
10 years	197·2	136·95	9·03	51·22	69·44	4·58	25·98
10 years	137·7	93·6275	4·6	41·94	66·8	3·28	29·92
11 years	239·45	187·205	9·83	42·41	78·18	4·11	17·71
14 years	311·941	265·161	7·0025	59·7775	79·9	2·1	18·0

TABLE III

Age	Sex	Body Weight (lbs.)	Body Height (ins.)	Race	Calc. Vol. (cmm.)	Volume / Weight	Volume / Height
4 years	F.	30	39½	European	77·432	2·58	1·96
7 years	F.	48	54	Bantu	150·240	3·13	2·78
3½ years	M.	30	38	European	74·675	2·49	1·97
13 years	M.	90	64	Msutu	252·570	2·81	3·95
Stillborn	M.	3¾	17	Zulu	43·260	11·54	2·54
8 months (prem.)	M.	5	17½	European	32·065	6·41	1·83
24 hours	F.	6	17	Bechuana	68·69	11·45	4·04
5 months	M.	7½	20	Msutu	52·725	7·03	2·64
Stillborn	F.	6¾	21	Msutu	62·032	9·93	2·95
5½ years	F.	40	39	European	138·127	3·45	3·45
2½ years	F.	16	29	Bantu	79·125	4·95	2·73


THE VOLUME OF THE PITUITARY GLAND
AT DIFFERENT AGES
300
250
200
150
100
50
CUBIC MILLIMETRES
TOTAL VOLUME
PARS ANTERIOR
PARS NERVOSA
PARS INTERMEDIA
6
8
10
12
14
AGE IN YEARS

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STUDIES IN MALNUTRITION AMONG NON-EUROPEANS

BY

Joseph Gillman, Theodore Gillman, Winifred M. Till, Joel Mandelstam and Christine Gilbert.

University of the Witwatersrand, Johannesburg.

Read 4th July, 1944.

(1) *Vitamins and Disease*, by *Joseph Gillman.*

Ignorance of the factors responsible for disease is a great handicap. Disease always offers a potential threat to life. Pain and the instinct for self-preservation are potent forces and in the absence of knowledge sick people are driven to seek relief in all sorts of queer ways by appealing to mystics, quacks and charlatans. The doctor, too, is affected by ignorance of disease, for his prestige in society is dependent on his capacity to relieve pain, to heal the sick and restore them to health. In the past the doctor has been able to conduct his practice with a limited knowledge. To-day medicine is becoming highly specialised, thousands of facts are accumulating and in the absence of a unifying concept or a satisfactory theory of disease, not only is medicine leading itself into a morass, but many valuable facts cannot be fully evaluated and applied.

The concept of the bacterial origin of disease introduced by Pasteur did much to help medicine in attacking disease especially as it provided the background for the understanding of Virchow's observations on the role of the cells in inflammation. However, after fifty years of experience this theory, in its present form, has failed to provide a satisfactory solution to many problems encountered in the clinic.

The failure of this theory is largely due to the fact that disease is regarded as the antithesis of health and that such disease is initiated by a specific cause which if removed would lead to the restoration of health. The theory of cause and effect in its simplest form is the one which underlies the present practice of medicine and of medical research.

Malnutrition to-day is regarded as a most important factor in determining the onset of many unrelated types of diseases. With the discovery of the vitamins it was to be expected that many forms of deficiency diseases should be treated by the administration of highly potent vitamin concentrates. The argument used is that since the lack of vitamins can cause disease, then obviously the addition of these essential food substances to the diet would restore the patient to health.

While the deficiency of essential substances from the diet undoubtedly does cause disease, however, once such a disease

has become established the adaptation of the organism is such that the addition of these missing substances may no longer heal the disease and, in fact, may aggravate it even exciting new types of reactions.

Experimentally it has been shown that in animals on a thiamine deficient diet the liver becomes fatty. The addition of thiamine, however, intensifies the liver lesion.

However, despite this information, thiamine and other vitamins are still extensively used in clinical medicine in the treatment of so-called specific vitamin deficiencies.

Pellagra is defined in the literature as a disease due to nicotinic acid deficiency. While in many cases the addition of nicotinic acid does apparently improve the clinical condition it has been repeatedly recorded that soon after the commencement of treatment the patients develop acute neuritis and exhibit other abnormal reactions. Spies and his co-workers have shown that pellagrins suffering from relapses while receiving massive doses of nicotinic acid can be improved by riboflavin.

Hitherto the improvement obtained by vitamin therapy has been assessed largely on the general clinical picture. Our group has shown by means of the liver biopsy method that many patients discharged as cured actually leave the hospital with different grades of liver damage. It is quite clear that improvement on clinical grounds may be entirely misleading and that patients may continue to suffer the ill-effects of the deficiency disease. Moreover, during the last 3-5 years more than 50 per cent. of malnourished children have died despite the administration of vitamin concentrates and a full diet.

In studying severe malnutrition in children we have been able to show that many of the cases die and the livers become much worse when treated with vitamins. We have been driven to the conclusion that in severe malnutrition affecting children not only are vitamins not life-saving measures, but they may actually hasten the death of the children. The most satisfactory treatment for this condition we have found to be an extract of hog's stomach. The improvement noticed with stomach extract cannot be ascribed to its vitamin or protein content since this extract is administered in relatively small amounts. In adult pellagrins the response to stomach extract has been remarkable and in many respects superior to any known vitamin therapy used up to the present.

Thus in children and adults it is possible to alleviate the acute reactions of deficiency diseases not by the exhibition of vitamins but by some other substances whose vitamin content is extremely low.

The work of the group seems to indicate that while many diseases can be attributed to the lack of vitamins, once a disease is established vitamin administration may not necessarily cure

that disease. It is therefore necessary to approach deficiency diseases and their treatment by other methods.

In our opinions it is unwise to patch up a bad diet by the addition of concentrated vitamins in tablet or biscuit form such as has been recommended recently by some of our scientific bodies. The best cure is prevention and no substitute for a balanced and adequate food can prevent the scourges of malnutrition. The science of nutrition is still too young to offer final advice on the best diet for the people.

(2) *Diet and Death in Bantu Children*, by *Theodore Gillman.*

During the past five years there has been a rapid increase in the number of native patients suffering from acute and chronic malnutrition admitted to the Non-European Hospital, Johannesburg. The increase in the incidence of severe forms of malnutrition among children and infants is particularly marked. Thus during the years 1937-1939 there was a total of 177 cases admitted, i.e. an average of 59 cases per annum whereas between January, 1940, and May, 1944, no less than 423 children suffering from multiple deficiencies were treated, i.e., an average of 96 per annum. Moreover, the severity of the condition has also increased as is evident from the higher mortality rate. In 1938 twelve of the forty-two children died—a death rate of 27 per cent. whereas between 1940 and 1943 the death rate averaged 45 per cent. The following is an analysis of the number of children admitted to the hospital during 1938 and from 1940 to 1943:—

	Total.	Died.	R.H.T. *	Cured.
1938	42	12 (27%)	10	20 (50%)
1940	52	23 (44%)	9	20 (31%)
1941	74	31 (42%)	10	33 (44%)
1942	116	55 (48%)	13	48 (42%)
1943	87	41 (46%)	16	30 (34%)

* Refused hospital treatment.

Whereas classical pellagra is the most frequently observed manifestation of acute malnutrition among the adults, the clinical picture seen among the children is more varied and certainly more complicated. Children between one and three years of age are the most frequently afflicted. The disease is apparently acute in onset. The first signs are irritability, loss of appetite, diarrhoea or constipation (most frequently the former), skin rashes and occasionally swelling of the eyes during the night By the time the child is brought to the hospital it is frequently moribund. Many babies die within a few days of admission. At this stage there is extensive and very severe oedema. The eyes are completely closed, the hands and feet are swollen as are the genitalia. The skin covering the inner aspects

of the thigh, the buttocks, genitalia, neck and armpits frequently sloughs, leaving a raw red exquisitely painful ulcerating surface. The lips are either denuded or have deep painful linear cracks—the typical cheilosis described by Sydenstricker, Sebrell and others. The tongue is smooth and shining. The eyes, too, are frequently affected and the conjunctivae are injected. These children lose their hair or become grey and the scalp is frequently ulcerated. They look old, wizened and listless. The stool is either green and watery or may be pale, bulky and very offensive and fatty. The liver, too, shows extensive fatty change.

The tragic feature about these patients is that firstly their appetite is very poor and they do not eat and, secondly, the administration of accepted forms of therapy such as vitamins and milk concentrates, and blood and serum transfusions are usually of no avail in avoiding death and frequently aggravate the disease. The small percentage of cures, an average of 38 per cent. during the past four years, among these children indicates the severity of the condition and the paucity of our knowledge concerning this form of malnutrition. Moreover, we have during the past four years accumulated irrefutable evidence to show that even those children that are discharged from the hospital as "cured" have residual damage, particularly of the liver, which with the inevitable repetition of dietary insults to which they are subjected, results ultimately in chronic disease of the liver which kills in early adult life.

Our recent researches on this problem, however, indicate that we have now available a much more reliable and valuable cure for this severe form of malnutrition.

Besides the high mortality amongst these cases due to the dietary deficiency itself, these children are highly susceptible to all forms of infection. They frequently develop pneumonia, diphtheria and tuberculosis. Moreover, once an infection has set in it progresses rapidly with a fatal termination. Perhaps the high mortality among these patients is in part attributable to the hospital conditions. In Johannesburg there are about 25 beds to serve the entire Non-European child population as compared with over 130 beds for European children. The Non-European Hospital children's ward is always overcrowded and it is most unusual to find a cot with less than two children. Epidemics of diphtheria and measles are frequent in the ward. Since septic surgical cases, pneumonias, tuberculotics and patients suffering from gastro-enteritis all lie in the same ward and frequently in the same cot as children under-mined by malnutrition, it is inevitable that complications should occur which kill the infants.

It has been repeatedly stated by eminent authorities that for every subject suffering from acute malnutrition there are, in the same community, nine others who are chronically malnourished. Drs. Kark and le Riche (1944), after an extensive

survey of African school children in the Union, record that in most districts more than 50 per cent. of children evidence some obvious sign of malnutrition or ill-health secondary to malnutrition. In some areas more than 90 per cent. of the children are malnourished. They conclude their recent report as follows:—

"The thin, round-shouldered, flat-chested, pot-bellied child with spindly legs was such a common sight that it can only be concluded that many were on the borders of starvation. The problem is not only one of providing this or that particular food factor, but rather a need for a general increase of all foodstuffs which will tend to build up a healthy Bantu population, averting starvation as well as the many more specific deficiency diseases."

With this evidence of the tragic nutritional status of many native children in our country, either we must be prepared to feed the people or hobble along with a dead-weight of blind, cripples and a grade 3 native population.

Under the present war conditions deficiencies in the quantity and quality of the food available to the urban African child are responsible for more deaths and chronic illness among urban African children than any other single factor. The administration of vitamins or vitamin-fortified diets of a limited character cannot replace the proper feeding of the people. At present our knowledge of nutrition is so limited that to use excessive quantities of vitamins either for the treatment or the prevention of malnutrition must be regarded as unscientific and even as dangerous.

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(3) *Diet and the Genital Tract*, by *Winifred M. Till.*

It has been shown by many workers that the absence of various vitamins from the diet of rats has a definite effect upon the reproductive organs. Vitamin A is necessary for the normal activity of the germinal epithelium in the testis. A lack of the vitamin leads to a sloughing of the germinal epithelium into the lumen and spermatogenesis is impaired. The tubules become reduced in size.

In the females vitamin A deficiency is associated with keratinization of the vaginal and uterine epithelia. In rats deprived of vitamin E there is inhibition of spermatogenic activity, the spermatids fuse and spermatocytes form characteristic multi-nucleate giant cells. In the female E-deficient rat the processes of oestrus and ovulation are normal, but established pregnancies are terminated by resorption of the embryos.

In rats fed on a diet of mealie-meal porridge and sour milk the testis is damaged and many of the lesions resemble those found in vitamin E deficient male rats. It was found, however,

that the degree of testicular damage varied considerably. for whilst some rats possessed a sufficient number of normal tubules to remain fertile, in others the atrophy was complete.

In female rats fed on this same diet many abnormalities have been observed. Most striking was the fact that although about forty females were placed on this diet, not more than five litters were produced in about fifteen months. In the majority of the females which became pregnant the embryos underwent degeneration and were resorbed. After resorption the oestrous cycle was re-established and the uterus appeared reddish brown in colour. Even in rats which did not become pregnant massive corpora lutea were seen and in one case an abscess was formed in the uterus. In two of the cases examined one showed excessive haemorrhage into the corpus luteum, practically all the tissue being replaced by a clot of blood and in the other there were greatly dilated blood vessels with slight haemorrhage. Haemorrhagic corpora lutea are not normal findings in the rat.

The maintenance of pregnancy in the rat is dependent on the functional integrity of the corpus luteum and if this is damaged by haemorrhage the embryo dies. It is highly probable that the absorption of embryos in the rat, a constant finding in the rats on a diet of mealie-meal and sour milk could be explained by the destruction of the corpora lutea by haemorrhage rather than to a direct effect on the utero-placental tissues.

Owing to the great variations in the nature of the testicular lesions it was suggested that the lack or deficiency of vitamins could not be solely responsible for these injuries, especially as in every instance the livers were damaged.

In the Bantu, chronic liver disease is very common in malnutrition and in severe cases testicular atrophy and gynecomastia may be frequently encountered. Aberrations of the menstrual cycle in the Bantu can also be attributed in part to hepatic disease of nutritional origin, since the cycle is re-established when the diet is improved and biopsies have revealed a simultaneous improvement in the structure of the liver. It is possible that many of the abortions recorded in Bantu females may be due to malnutrition and not only to venereal disease.

(4) *Diet and Distributed Carbohydrate Metabolism*, by *Joel Mandelstam.*

The Bantu in this country subsist on a diet high in carbohydrate but lacking in other essential factors. Alternatively, their diet may contain unbalanced constituents leading to the impairment of organs concerned in carbohydrate metabolism, particularly the liver.

The oral glucose tolerance test has been extensively used in the study of carbohydrate metabolism and we have employed it as an indication of disturbance in dietary conditions. The tests

were carried out on rats fed on a diet of mealie-meal and sour milk. Only three of twenty-seven animals displayed a normal curve. The mean curve showed a slow rise, the peak being reached only after 90 minutes and the return to the fasting level was retarded. In normal rats the peak is reached in 30 minutes and there is a sharp fall in the blood sugar level thereafter.

In cases of pellagra at the Non-European Hospital, Johannesburg, the same type of curve has been found as in the rats fed on mealie-meal and sour milk.

The oral glucose tolerance test, however, suffers from a number of disadvantages. Firstly, the rate of absorption of glucose in any particular case is an unknown factor which may seriously affect the test especially in cases of pellagra where there may be a pathological condition of the stomach and intestine. Secondly, there is the difficulty of assessing the results of the test. For this purpose a number of criteria have been used, viz.,

(a) The value of the fasting sugar,

(b) Time taken to reach a peak value,

(c) The peak value,

(d) Time taken to return to the fasting level.

Opinions differ on each of these points, with the result that there is no agreement as to what constitutes a normal curve. Furthermore, the expression of results is complicated, five or six blood sugars having to be reported for each curve.

Substitution of intravenous administration of glucose for the oral method leads to several advantages. The absorption factor is eliminated and the results can be expressed in a less cumbersome fashion by applying the methods of Hamilton and Stein (1942). and Greville (1943). These writers showed that the rate of disappearance of injected glucose is proportional to the concentration of sugar in the blood at that time. This is the relationship holding for a mono-molecular chemical reaction, and the rate of utilisation of glucose can be expressed by a single figure, the velocity constant. This method has proved superior to the oral glucose test for the study of carbohydrate metabolism in normals. and in cases of liver damage.

In 32 tests on normal subjects the value of the velocity constant (multiplied by 100) lay between 1·2 and 3·5 with a mean of 2·2. In cases of known liver damage the value was almost invariably lower, e.g., in three cases of carcinoma of the liver the values were 0·9, 0·8 and 1·2 and in a case of catarrhal jaundice 1·1. Similar results have been found in baboons showing marked liver damage as a result of carbon tetrachloride poisoning.

Intravenous glucose tolerance tests were also carried out on cases of pellagra at the Non-European Hospital. In eight of

eleven severe cases the velocity constants also fell below the limit of normal range, while in three mild cases the values were normal.

It thus appears that rats fed on mealie-meal and sour milk exhibit the same type of oral glucose tolerance curve as human dietary deficiency cases. Furthermore, in pellagra we find the same form of intravenous curve as in cases of known liver damage viz., carcinoma of the liver in humans and carbon tetrachloride poisoning in baboons.

These results were correlated with liver biopsies in humans, rats and baboons. It was found that all cases of pellagra with an abnormal intravenous glucose tolerance curve exhibited marked liver damage, but in mild cases, though the histological picture was still pathological, the glucose tolerance was normal. The results obtained with the oral glucose tests in rats were similar.

We thus found that in rats fed on mealie-meal and sour milk, and in cases of pellagra among the Bantu, there was definite liver damage, varying from fat infiltration to cirrhosis, with a corresponding disturbance in the carbohydrate metabolism.

Note.—Part of the expenses incurred in this investigation was defrayed by a grant from the South African National Research Council and Board.

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(5) *The effect of a diet of mealie-meal and sour milk and of mealie-meal and Kaffir beer on baboons and monkeys*, by *Christine Gilbert.*

Workers in the Department of Anatomy have shown that when young rats are fed on a diet consisting solely of mealie-meal and sour milk the rate of growth is not seriously impaired and that the animals mature almost normally. During the first three or four months there are no clinical signs of the rats being unhealthy and it is only much later that the external lesions such as incrustations on the whiskers and eyes and a rusting of the coat are observed.

Histological evidence reveals, however, that within the first fortnight after commencing the diet the liver cells accumulate fat globules. The functional efficiency of the liver deteriorates steadily and after a period of 12-18 months whole lobes may disappear and others become extensively cirrhotic. Over 60 per cent of the rats become blind, live young are seldom born and almost every organ in the body is injured to some extent.

It was suggested that the high incidence of blindness, the frequent appearance of sterility and the invariable occurrence of

severe liver damage among the Bantu population and in apparently "normal, healthy" people, compared so strikingly with similar lesions produced experimentally in the rat, that these lesions might be attributed in large part to the deleterious effects of a badly balanced diet. To test this analogy on animals more closely related to man the experiments were repeated on primates, and eleven animals (six baboons and five monkeys) received a diet of mealie-meal and sour milk and a further four baboons received mealie-meal and kaffir beer which was supplied *ad lib.*

Liver biopsies at the end of the first month demonstrated the steady accumulation of fat in the liver. These changes in the liver cells were intensified after two months and at this time examination of the teeth and gum's revealed severe lesions. In the baboons the gums were haemorrhagic while in the monkeys there was actual erosion of the gum margins and dental caries, associated with a loosening of the teeth.

All the animals began to look shaggy and untidy; their coats lost their shine and although the animals still ate their food they were dull and listless. In addition, the monkeys showed a peculiar patchy de-pigmentation of the hands and soles of their feet. At the end of three and a half months all the monkeys and baboons had died: the onset of death was sudden. The animals became acutely sick only two to three days before death, when they developed severe enteritis with blood and mucus in the stools. Once this syndrome commenced the animals deteriorated rapidly, became severely dehydrated and died.

The findings at post-mortem examination in both monkeys and baboons were similar. The alimentary tract was most severely involved. The dental lesions have already been discussed; the livers, although not enlarged, were pale in colour and on microscopical section showed only an intensification of the fatty changes which were observed at an earlier date in the experiment. The gastric mucosa was consistently atrophic and frequently showed evidence of small petechial haemorrhages. The mucosa of the large bowel, on the other hand, was extremely congested and grossly hypertrophic. The lesion commenced in the caecum and became progressively worse in the transverse and descending colon where the mucosa was frequently gangrenous. Another constant feature of the post-mortem examination was the enlargement, accompanied by severe congestion or haemorrhage of either one or both adrenals.

In some animals the kidneys were grossly fatty, the hearts in two instances were soft and fatty and in one monkey there was haemorrhage into the muscles, the knee-joints and into the spinal canal.

The second group of animals, on a diet of mealie-meal and kaffir beer, became acutely ill after the first week and

deteriorated rapidly until the 12th-14th day when all the animals died. For the first 4-5 days the animals had good appetites and drank the beer readily. Thereafter they became disinterested in their surroundings and would not respond to anyone trying to attract their attention. They lost their appetites, drank very little beer, and diarrhoea and vomiting became continuous. Like the monkeys and baboons fed on mealie-meal and sour milk, they died suddenly.

The post-mortem findings were almost identical with those described for the monkeys and baboons fed on mealie-meal and sour milk, with this addition that the lesions (apart from dental) appeared to be intensified. The absence of dental lesions is accounted for by the extremely short period during which the animals were kept alive on the diet.

There is little doubt, from these preliminary dietary experiments on a limited number (16) of primate animals, that mealie-meal porridge supplemented either by sour milk or kaffir beer cannot keep the animals alive for a period longer than 3½ months and that this period may even be shortened to 14 days; the animals do not grow on these diets but rapidly become emaciated. Within the first two weeks of the experiment this diet initiates fatty changes in the liver and later atrophy of the gastric mucosa. The animals develop an acute ulcerative colitis with gangrene of the colonic mucosa. Death is usually sudden due to adrenal apoplexy. If the animals survive for two to three months dental lesions which differ only in their severity are always present.

Finally, in our experience, kaffir beer, in combination with mealie-meal, served only to accelerate and intensify the lesions of the alimentary tract which were produced over a longer period of time in animals fed on mealie-meal and sour milk.

These findings throw considerable light on the high mortality rate among Africans and in particular among the children. It is common knowledge that the most frequent cause of infant deaths among backward people including the South African Bantu is gastro-enteritis. It is generally believed that this bowel condition is primarily due to bacterial infection. These experiments demonstrate that an improper diet can precipitate fatal gastro-enteritis in previously healthy animals and that in children and in adults such diseases may also be of dietetic origin.

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IMPROVED METHODS FOR THE DEMONSTRATION OF MITOCHONDRIA, GLYCOGEN, FAT AND IRON IN ANIMAL CELLS

BY

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Read 4th July, 1944.

An accurate assessment of the inter-relationship of the various constituent elements of a cell can only be made with the aid of such techniques as will satisfactorily display these components simultaneously in a single preparation.

Since the investigations of the group of workers in the Anatomy Department were directed towards the problem of the reactivity of the liver cell in nutritional disturbances, it became necessary to perfect the techniques for demonstrating mitochondria, glycogen, iron and fat. The existing techniques were found to be unsatisfactory and very erratic. Moreover, in view of the value of the material as well as the large number of specimens needed for such a study, it was desirable to perfect the techniques in such a way as to make them consistently reliable, and to be of such a nature that several features of the cytology should be demonstrated in the same preparation.

The object of this paper is to describe improvements in the techniques for displaying mitochondria, glycogen and iron in liver cells of man and of animals.

MITOCHONDRIA.

One of the most serious difficulties in staining for mitochondria by the aniline fuchsin-methyl green technique has been that of differentiating the fuchsin in the mitochondria in such a way that the mitochondria are tinted red while the cytoplasm, nucleus and interstitial tissue are suitably stained at the same time. The use of phosphomolybdic acid as a mordant after staining with aniline fuchsin has greatly facilitated this process of differentiation and also improved the staining capacity of methyl green.

The following technique has yielded brilliant results:—

1. Fix small pieces of tissue for 24 hours in Helly-osmic fluid.
2. Wash for 24 hours in running water.
3. Dehydrate rapidly—10 minutes in each alcohol to avoid hardening of tissue.

4. Clear in chloroform and embed in paraffin—sections are cut at 3 microns.
5. Hydrate and immerse sections in 3 per cent. aqueous solution of potassium permanganate.
6. Decolourise in 5 per cent. oxalic acid solution. Rinse in distilled water and stain for 1-1½ minutes in Altmann's Aniline acid fuchsin (70 per cent. acid fuchsin in aniline water). The stain must be poured on the slide and heated gently until it steams.
7. Rinse in aqua dest. and differentiate until mitochondria stand out sharply against the pale pink background of the cytoplasm.
8. Immerse for ½ minute in 5 per cent. phosphomolybdic acid.
9. Rinse in aqua dest. and stain with 0·3 per cent. Methyl green until the section is green. The slide is then transferred into 95 per cent. alcohol.
10. Rinse in 30 per cent. acetic acid in alcohol. Dehydrate and mount.

COMMENT.

Using this method the mitochondria stain red, the cytoplasm pale green, chromatin material green and nucleoli red. The fat is fixed and demonstrated as black globules by the action of the osmic acid in the fixative.

In the method previously used, the sections were stained with acid fuchsin and methyl green only. Using that technique it was difficult to control the stain because the methyl green differentiated the acid fuchsin too rapidly and the subsequent dehydration removed the green colour. The results were unsatisfactory for the following reasons:—

1. The staining was patchy.
2. Mitochondria were shown in only a few cells.
3. The cytoplasm was not counterstained.
4. Nuclear structure was not clearly defined.

With the new method, all cell inclusions are well demonstrated. The phosphomolybdic acid has a double action—it fixes the acid fuchsin in the mitochondria and nucleoli, and acts as a mordant for the methyl green. Previously, 1 per cent. methyl green was used, but this proved to be too strong and staining was too rapid to control. If the acetic acid is not used after rinsing in 95 per cent. alcohol, the cytoplasm is not clearly defined, as the acetic acid acts as a clearing agent.

The resulting picture is one in which all the structures are sharply demarcated and there is no difficulty in distinguishing one from another.

This staining technique can be applied to other tissues and can be used after fixation in Regaud-acetic and Da Fano's fixatives, provided the staining times are modified for different

tissues. It is only necessary to use potassium permanganate and oxalic acid when Helly-osmic fixative is used.

Glycogen.

The usual methods recommended for the demonstration of glycogen in tissues by the Best's carmine stain usually necessitate a fixative containing a high percentage of absolute alcohol in order to preserve the glycogen. Quite apart from the violent effect of alcohol on delicate cytoplasmic elements, staining with Best's carmine reveals the sugar to be localised to one pole of the cell. It is clear to all investigators that such polarisation of the glycogen is an artefact and does not exist in the living cell. The only value of the available technique for glycogen is that it does give some indication of the amount of this substance in tissues, but obviously its topographical relationship in the cell is grossly distorted.

The following technique was devised in order to obtain a more precise indication of the distribution of glycogen in the liver cell.

Tissues are fixed as described above for mitochondria. After fixation in Helly-osmic fluid the tissues can be washed for 24 hours in running water without affecting the glycogen. The tissues are embedded in paraffin and cut at 3-4 microns and then stained for glycogen as described by Gatenby and Painter (1937). The tissues are counterstained for two minutes in Heidenhain's haematoxylin. Differentiation is performed with acid alcohol and not with ferric alum.

In these sections the nuclei are stained black, the glycogen appears in the form of fine red granules distributed evenly throughout the cytoplasm. By fixation in osmic acid, the fat persists as jet black or brown globules within the cell.

This method for the demonstration of glycogen is superior to any yet described in the literature. Helly-osmic fluid is regarded as an excellent cytological fixative and when used in combination with Best's carmine stain, eliminates all those precautions usually necessary when the tissue is fixed in alcohol. The glycogen is rendered insoluble in water after fixation in the Helly-osmic fluid. The sections can be treated as any ordinary section.

Superficial examination of sections stained by this method gives the erroneous impression that some of the glycogen in the cell is washed out as compared with alcohol fixed tissues. Control sections, where both the alcoholic and Helly-osmic methods have been used on the same tissue reveal that none of the glycogen has been washed out of the cell after fixing by the method recommended above, but that owing to the more uniform distribution of glycogen, the intense colour of the Best's carmine stain is not so obvious. The ptyalin test for glycogen in the Helly-osmic fixed tissue is positive.

This method eliminates the injurious effects of high grade alcohols on the tissues and in view of the preservation of the fat globules materially assists in the study of the relationship between fat and glycogen in the same cell.

IRON.

According to Gatenby and Painter (1937), it is not always possible to obtain a positive test for iron pigment in cells unless the compound has been broken down and the iron unmasked. To achieve this break-down it is suggested that formalin or alcohol fixed sections be treated for 24 hours in the incubator at 35°C before applying the Prussian blue reaction.

The application of a modified Pearl's method recently described by Highman (1942) served to indicate that despite the shortening of the staining time, some of the pigment suspected to contain iron did not give a positive reaction.

The modification of the method in our laboratory now enables us to demonstrate iron in pigment which remained negative with all the other tests. Formalin or Bouin fixed material is embedded in paraffin. The sections are flooded with a hot mixture consisting of equal parts of 3 per cent. Hydrochloric acid in 70 per cent. alcohol and 2 per cent. potassium ferrocyanide. Moreover, it has been found that if the slide is gently heated until the steam rises, more of the pigment reacts positively. Such sections can be counterstained with 1 : 6000 basic fuchsin as recommended by Pearl. The sections are rapidly dehydrated and mounted in balsam or clarite.

This method has also been applied to frozen sections and allows the fat and iron in the same section to be demonstrated simultaneously. The iron reaction is applied first and thereafter the sections are stained in the usual way with Sharlach R and Ehrlich's haematoxylin, when the iron stains blue green and the fat red to orange.

I wish to acknowledge my indebtedness to Dr. Theodore Gillman and to Dr. Joseph Gillman for the useful suggestions which led to the perfection of the above methods.

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A NOTE ON THE BLOOD SUPPLY OF THE BRAIN OF GALAGO WITH REFERENCE TO SHELLSHEAR'S NEUROVASCULAR UNITY CONCEPT

BY

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Read 4th July, 1944.

While the morphology of vertebrate brains has received a great deal of attention, the blood supply has generally been neglected. Shellshear (1) however, realised that no study of structural development was complete unless the corresponding modifications in the vascular supply were taken into consideration. By studying the brain in this manner he was able to establish a neuro-vascular relationship. According to Shellshear a morphologically and functionally distinct area supplied by its specific blood vessels constituted a "neuro-vascular unit" which remained phylogenetically and ontogenetically constant.

In the Galago brain the blood vessels of the quadrigeminal bodies form part of such a neuro-vascular unit. Some of the mesencephalic arteries arise from the posterior cerebral artery and others from the superior cerebellar artery. In the guinea-pig and kangaroo these mesencephalic arteries arise from the posterior communicating artery. Whatever the origin of these mesencephalic arteries, they always supply the region of the mid-brain and do not encroach on adjacent functionally different areas. Moreover, the supply of the mid-brain by the specific blood vessels is constant in all brains thus far examined and in this way would support Shellshear's hypothesis.

The constancy of the arterial supply to the hypothalamus and the retina as well as the serially arranged vessels arising from the basilar artery and running to the areas adjacent to the fifth, sixth, seventh and eight cranial nerves are further examples supporting the validity of the neuro-vascular unity concept.

A lowly mammal like Elephantulus (2) has three cerebellar arteries supplying equal areas of the cerebellum. If these areas with their respective vessels are called neuro-vascular units, according to Shellshear's thesis, a more highly evolved cerebellum like that of Galago, which incorporates the primitive areas of a lower brain, should have distinct vessels supplying these

different areas. This arrangement, however, is not the case because the superior cerebellar artery supplies the whole cerebellum.

In Galago, the distribution of the blood supply in some parts of the brain would lend support to Shellshear's hypothesis but, in the cerebellum at least, the concept is not upheld. The reason for this exceptional instance in the cerebellum is not apparent at this stage and further investigations are necessary before it is possible to accept Shellshear's hypothesis in its present form.

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COMPARATIVE EFFECTS OF CLIMATE AS STUDIED ON WHITE RATS IN VARIOUS SOUTH AFRICAN LOCALITIES

BY

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With 1 Text Figure.

Read 4th July, 1944.

1. Introduction.

Of all the various types of research work on animal biology, that concerned with the influence of climate on animal life constitutes one of the most complex problems. This is due to the fact that climate is a composite entity made up of several factors, all of which are highly labile and therefore mutually variable. As a result no satisfactory method has been evolved for the quantitative measurement of climate as an environmental unit, despite all available data concerning individual meterological phenomena. Likewise great difficulty is experienced in the assessment of animal reaction to climate, seeing that the various organ systems are constantly being adjusted, both in structure and in function in a mutual endeavour to maintain a balance between the internal environment of the body and the external climatic forces.

Despite these difficulties, however, the mass data already collected in this field affords evidence that bioclimatology is steadily forcing itself into the forefront as an important line of scientific research.

2. Object of Rat Experiments.

The reaction of various types of cattle to environment, including that of climate, is being studied by Bisschop and collaborators at Armoedsvlakte, Bechuanaland, and by Bonsma in the lowveld of the Northern Transvaal. In order to gain further information of the effects of climate as such on animals throughout South Africa, an experiment was started in November, 1942, on white rats of the Wistar strain. Previous experiments conducted at Onderstepoort fully confirmed the findings of workers elsewhere that the Wistar white rat, inbred for many generations, serves as a very useful mammal for studying biological response to different meteorological

phenomena. In this connection its unpigmented skin and hairy coat, as well as the absence of functioning sweat glands, renders it particularly suitable in determining the effects of light and temperature.

The primary objects of this study were to measure and subsequently to compare a few important body reactions of white rats continuously exposed in an identical manner to the play of climatic forces in eight widely separated localities of the Union. No special attempt was made to collect complete meteorological data from the different stations during the course of the experiment, firstly because it presented various technical difficulties, secondly because it would have entailed an enormous amount of labour in computing and analysing all the meteorological findings, and finally because great difficulty was foreseen in the interpretation of the meteorological data and their correlation with the animal reactions. Seeing, however, that all the localities in which rats were exposed also served as routine meteorological stations, such data are available when required. In addition the daily maximal and minimal temperatures were recorded immediately above the rat cages.

To ensure a strict correlation between animal reaction and climate as such, great care was taken in the experiment to exclude all intercurrent effects of both diet and infection. Unless these two important environmental factors were rigidly controlled throughout, it was felt that no reliable information could be expected concerning the direct effects of different climates on animal life.

3. Planning of Experiment.

Briefly stated, the experiment was planned as follows:

(a) From large numbers of rats bred at Onderstepoort for this purpose, twelve males, two months old, were selected on weight for each of eight different stations. The groups were as uniform as could possibly be expected. Two wire cages, specially fitted for feeding, watering, and sanitation, each accommodating six rats, were despatched to the various stations at the end of October, 1942.

(b) Eight identically constructed wooden shelters were erected on open, selected spaces, one at each of the various stations. The shelters were devised to protect the animals from rain and also from direct sunlight, except for one hour after sunrise and one hour before sunset. For the rest they were exposed day and night to all the natural climatic forces, including temperature variations, wind, humidity, sky radiation, altitude, etc.

(c) The diet consisted of a standardised, fully balanced dry mash distributed simultaneously to all the centres every two months. No other food was allowed. All animals were fed daily, and the food consumption calculated on a weekly basis.

Likewise the groups were watered daily from special bottles and the daily consumption recorded. The base of each shelter was screened with wire netting, thus excluding animal borne infections from wild rodents, birds, etc. (See photo.)

(d) All animals were ear numbered, thus enabling them to be weighed individually once per week (later once per month) on dates laid down for all stations. At the same time each animal was examined for its clinical state of health, and monthly records of all data forwarded to Onderstepoort.

4. Distribution of Animals.

The following eight centres (five inland and three coastal) were selected. Geographically they are widely separated. Each carries a distinct flora characteristic of a widespread area while climatically they may be regarded as representing the most divergent climatic conditions obtainable in the Union of South Africa. As indicated below, this work was undertaken as a collaborative study in which various officers in the Department of Agriculture willingly participated.

1. Messina (Experimental Farm).
   Limpopo valley. Mopani scrub. High temperature. Low rainfall (10-15 inches). Collaborator, J. F. Badenhorst.
2. Onderstepoort (Veterinary Research Laboratory).
   Transition. Transvaal highveld to bushveld. Rainfall 25-30 inches). Collaborators, G. Riemerschmid, R. Clark, G. Elder.
3. Vryburg (Armoedsvlakte Research Laboratory).
   Bechuanaland grassveld. Rainfall 15-20 inches. Collaborator, J. M. Fourie.

4. Ermelo (Nooitgedacht Station).
   Eastern Transvaal highveld grass. Temperature mild to very cold Rainfall ± 30 inches. Collaborator, H. de Lange.
5. Middelburg (Cape) (School of Agriculture).
   Typical karroo flora. Rainfall low (10-15 inches). Collaborator: L. Roux.
6. Stellenbosch (Faculty of Agriculture).
   Western Province winter rainfall area. Rainfall 30-40 inches. Coastal. Collaborator, O. T. de Villiers.
7. Umtata (Veterinary Station).
   Transkei grassveld. Rainfall ± 30 inches. Coastal. Collaborator, W. F. Lamprechts.
8. Umfolosi (Nagana Research Station).
   Zululand lowveld. Grass and trees. Temperature high, humid. Rainfall ± 40 inches. Coastal. E. Kluge.

5. Results.

The accompanying table presents the average monthly body weights of the experimental animals over a period of eighteen months, i.e. during the summer 1942/43, winter 1943, and summer 1943/44. As the data concerning food and water consumption have not as yet been analysed statistically, these will not be considered in this report.

From clinical observation of the animals and a statistical analysis of their body weights, the following represents the main results achieved from the experiment:

1. From a total of 96 rats, only two deaths from unknown causes occurred at different stations within the first three months. The rest of the rats remained clinically healthy throughout a period of ten months from November, 1942. to September, 1943, i.e. a full summer season, followed by a winter season. The summer was marked by repeated spells of very hot weather, during which animals at certain centres showed signs of heat exhaustion, while cold spells of freezing weather were experienced during the winter. Despite these fluctuations, no deaths occurred as the result of temperature changes at any one of the eight centres.

2. From September, 1943, onwards, i.e. after ten months, deaths started to occur at irregular intervals, firstly amongst the Vryburg (Armoedsvlakte) group, to be followed thereafter by others from the remaining seven stations, until by the end of March, 1944 (eighteen months) a total of 34 animals had died.

3. With the exception of three cases, deaths in every instance was associated with a focal muco-catarrhal pneumonia, which was of the same character as that encountered amongst rats in previous bioclimatological experiments conducted at Onderstepoort. Such animals rapidly lost weight in the later

stages, the hairy coat became ruffled, while gurgling sounds became audible over the thorax. No specific organisms were to be found in lung cultures. This condition occurring amongst Wistar rats is, however, well known in America, and a good description of it is given in "The Rat in Laboratory Investigation," edited by J. G. Griffith and E. J. Farris (1942) According to these authors it is the most common morbid condition in adult rats after the age of one year, and is due in all probability to a genetically transmitted lethal factor.

4. In this connection it is of interest to record the sudden death of five rats from heat stroke at Umfolosi, Zululand, during a particularly warm spell in January, 1944. Post mortem of all five animals, however, revealed the typical lung lesions which strongly suggests that this had evoked increased susceptibility to acute heat effects. There is evidence that all the experimental rats will ultimately succumb to this characteristic form of pneumonia. Except for the deaths occurring earlier amongst the Vryburg animals there appeared to be an approximately uniform susceptibility to it at the various stations.

5. Statistical analysis of the monthly body weights reveals the interesting fact that, with the exception of two stations viz. Umfolosi and Vryburg, the average values for the remaining six stations continue to be very closely grouped round about the grand average throughout the whole period. Consequently it may be stated that no significant differences are to be found in the growth as revealed in the body weight of the animals at Messina, Onderstepoort, Ermelo, Umtata, Middelburg (Cape) and Stellenbosch.

With regard to the rats exposed at Umfolosi, Zululand their monthly average body weight remained very significantly higher throughout than that at any of the other stations. Contrarily that of the Vryburg animals was consistently and significantly lower than at the remaining seven centres.

6. By plotting two graphs, one of which represented the average monthly body weights for the six heavier rats and the other for the six lighter rats at each station it was found that the two curves continued parallel with each other.

The reason for this curious fact is that taken throughout the course of the experiment, six out of the twelve rats retained their relative class positions, while of the remaining six, three rats crossed over the higher to the lower group and three from the lower to the higher group, all within the first three months. Subsequently each animal retained its individual class position.

The above findings strongly suggest adaptation of the individual rat to its environmental conditions even at an early stage.

7. These considerations, however, are concerned merely with the body weights of the animals, and it still remains

an open question in how far body weight, taken by itself, constitutes a suitable index of animal vitality. The question therefore of what constitutes normality and all that falls within its range, can neither be fully conceived nor fully answered until biologists are in the position of clearly formulating an appropriate vital index in which are incorporated all the reactions of the animal body. Similarly a climatic index remains to be evolved before climate and its effects can be conceived as a single environmental unit in the life of the animal

Conclusion.

By exposing white rats under identical conditions, to the influence of climate in eight widely separated localities of South Africa it has been shown that nowhere has the climate been inimical to the life of the animals during an experimental period of eighteen months. Although usually considered to be a sensitive experimental mammal, the Wistar white rat, when kept on a uniform and adequate diet throughout, rapidly adapted itself to local climatic conditions.

While the influence of climate on the vegetal food supply of animals and on the incidence of specific disease conditions are striking enough, its direct effects on the animal body are far more subtle and misleading than is usually considered to be the case. This stresses the urgent necessity for rigid control of all intercurrent factors in bioclimatological investigations. Based on the above findings with rats, further research work should be undertaken on farm animals in order to assess the comparative effects of climate on them in different parts of South Africa. Such investigations should include animals kept at different levels of nutrition, and either exposed to certain types of infection or shielded against them. By these means the biological significance of climate will be brought into much clearer perspective.

AVERAGE WEIGHT OF RATS IN GRAMS.

	Umfolosi.	Onderstepoort.	Stellenbosch.	Umtata,	Middelburg.	Messina.	Ermelo.	Vryburg.	Grand Average.
1942.									
October ..	178·1	178·1	173·8	180·9	164·9	161·4	163·3	173·6	171·8
November ...	243·6	233·5	235·8	233·3	230·6	216·4	229·5	219·5	230·3
December ...	298·8	286·6	277·0	275·0	277·9	261·0	275·8	259·5	276·8
1943.									
January ...	326·2	309·0	296·8	303·0	293·7	281·2	294·3	274·8	297·8
February ...	338·0	319·3	305·2	318·2	313·6	292·2	303·0	279·9	308·7
March	338·5	327·0	312·5	321·9	319·3	305·5	312·8	292·7	316·3
April	349·8	337·3	327·3	331·3	318·4	314·8	320·7	293·9	324·2
May	337·3	332·3	337·9	343·4	322·6	331·5	330·4	290·8	328·3
June	359·9	329·9	339·9	330·8	332·8	338·9	328·8	288·8	331·2
July	369·7	339·6	347·4	336·9	326·0	339·3	331·3	299·9	336·3
August	362·8	344·3	353·8	339·1	361·9	341·7	324·9	282·8	338·9
September ...	389·7	359·0	362·9	346·5	350·5	347·1	342·7	330·7	353·6
October ...	392·2	368·6	365·9	351·2	352·1	340·8	350·6	307·2	353·6
November ..	393·9	394·6	372·0	347·3	347·9	358·5	337·1	317·5	358·6
December ...	394·7	395·7	388·5	354·9	352·8	352·7	338·0	325·0	362·8
1944.									
January ...	381·9	398·1	385·3	320·8	354·5	324·6	349·7	326;3	355·2
February ...	383·7	393·2	370·0	370·7	338·4	344·1	336·4	309·7	355·8
March	382·7	381·4	368·3	360·5	331·0	355·3	338·1	315·4	354·5

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NAGANA IN ZULULAND: PRELIMINARY REPORT ON THE INCIDENCE OF TRYPANOSOMES IN GAME

BY

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Read 4th July, 1944.

In fly belt areas where game animals are known to thrive in the presence of different species of tsetse flies of the genus Glossina, domesticated animals cannot survive. This is due to certain parasites, trypanosomes, which, if transmitted from the game animals to domesticated animals by means of the tsetse fly, which serves as intermediate host of various trypanosomes, causes the fatal disease of domesticated animals known as trypanosomiasis or nagana. The game animals act as carriers, harbouring the parasites in their systems without any ill effects to themselves. Apparently because game animals have this natural immunity the trypanosomes are usually present in very small numbers and are, therefore, difficult to demonstrate. The methods employed to demonstrate the parasites when investigating the incidence of trypanosomes in game consist of (a) direct microscopical examination of (i) wet blood preparations and (ii) stained blood and lymph gland smears; (b) biological tests.

For microscopical examination of wet preparations fresh blood is required. Immediately after a game animal is shot, blood is collected from the jugular vein into a sterile bottle containing a solution of potassium or sodium citrate to prevent the blood from coagulating. This blood can then be examined directly under a microscope in a small drop placed on a glass slide and covered with a cover slip. The trypanosomes, which are very active, can then be detected by their movement, which causes a disturbance of the blood cells. For this reason wet preparations should be examined as soon as possible whilst the parasites are still active. For the stained films blood and lymph gland smears are taken from freshly killed game animals. These are dried and specially prepared for microscopical examination, when those from positive cases can be recorded and kept. In both these methods of direct microscopical examination only a small quantity of blood is examined. If no parasites can be demonstrated by these means it still cannot be concluded that such an animal is not a carrier of trypanosomes.

For the biological test fresh citrate blood collected from a game animal is injected intravenously or intraperitoneally

into laboratory or domestic animals with the object of transmitting the infection. Up to 4 c.cs. of the citrate blood can be injected intraperitoneally into a white rat. Thus even if the parasites should be so rare in the game blood that they cannot be demonstrated microscopically, they may be present in sufficient numbers in a larger volume of blood to infect the white rat or any other laboratory or domestic animal used, and thus the diagnosis can be confirmed.

Nagana infection amongst the game animals of Zululand was investigated by four workers. In 1895 and 1903 Bruce established that trypanosomes were the cause of nagana, and found the parasites in certain species of game. In 1914 Mitchell showed, by means of biological tests, that 3 out of 48 head of game that he examined were infected. During September and October of 1915, Mitchell had another 43 head of game destroyed for blood transmission experiments with white rats, and obtained one positive result, from the blood of a young kudu. During the winter of 1922 Curson sub-inoculated blood from 39 head of game into dogs, goats and white rats, with negative results. He repeated the experiment during the summer months of December, 1922, and January, 1923, using another 24 head of game, but was unable to obtain positive results in dogs and goats which were used for the biological tests. Curson records live trypanosomes having been seen in fresh blood from a warthog, but the biological tests and stained films were negative. During the game eradication campaign in Zululand from 1929 to 1931, Neitz examined two lymph gland, two blood and two spleen smears from each of 616 game animals destroyed, and found seven head infected with pathogenic trypanosomes. These consisted of four cases of *T. vivax* and three cases of *T. congolense* recorded from four bushbuck, two kudu and one zebra. Smears examined from the 616 head of game were from zebra, wildebeest, kudu, waterbuck; reedbuck, duiker, steenbuck and klipspringer.

With the various methods which can be employed to establish the presence of trypanosomes in game it, therefore, still remains difficult to obtain positive results because of the small numbers of parasites which are present. By means of the direct microscopical examination of blood and biological tests the following species of game in Zululand were found to be carriers of trypanosomes: Kudu, buffalo, bushbuck, wildebeest, hyena, reedbuck, steenbuck (Bruce: 1895, 1903); impala, bushbuck and zebra (Mitchell: 1914); duiker and warthog (Curson: 1928); bushbuck, kudu and zebra (Neitz: 1931, 1933). If, however, one individual of a certain species of game is found to be a carrier of trypanosomes, then in a high fly density area a high percentage of infection would be expected to be found in such a species. With large numbers of fly engorging daily on a carrier of trypanosomes, the number of infected flies would

increase, which would spread the infection to other game It would, therefore, be expected that in the Umfolozi Game Reserve, with its high fly density the incidence of trypanosomes in game would be high.

In this connection further investigations are at present being made by the writer with a view to obtaining more information about the significance of the role played by game animals in Zululand as the natural carriers of trypanosomes The methods being employed are: (1) direct microscopical examination and (2) biological tests.

Microscopical Examination.—One blood and one lymph gland smear have been examined from 140 head of game and the results are as follows:—

TABLE I

Species of Game Animal	Number Examined	Negative	Positive
Warthog	39	37	2
Bushbuck	21	20	1
Wildebeest	15	15	—
Kudu	12	11	1
Steenbuck	9	7	2
Zebra	8	8	—
Waterbuck	6	6	—
Mpala	7	7	—
Rheebuck	6	6	—
Duiker	5	4	1
Nyala	4	4	—
Bush Pig	3	3	—
Cane Rat	3	3	—
Buffalo	2	2	—
	140	133	

Only suitable smears were selected for careful examination, and from the 140 head of game shot within the Umfolozi and Mkuze Games Reserves, 5 per cent. were found to be infected.

Biological Tests.—For the biological tests white rats were used. Fresh blood was collected from the jugular vein into a sterile bottle containing citrate, immediately after a game animal was shot. Without any delay, and usually within fifteen minutes after collecting the blood, ½ to 3 c.cs. of the fresh blood was injected intraperitoneally into the white rats. These rats were all marked with distinctive ear marks and daily records kept of all blood smears taken.

The results of inoculations of 61 rats injected are shown in the following table:—

TABLE II

Species of Game from which Blood Collected	Number of Rats Injected	Negative	Positive
Kudu	11	5	6
Zebra	10	10	—
Wildebeest	10	10	—
Waterbuck	1	1	—
Warthog	10	10	—
Reedbuck	2	—	.2
Rheebuck	1	1	—
Nyala, Mkuze Game Reserve	3	3	—
Impala, Mkuze Game Reserve	2	2	—
Steenbuck	4	3	1
Duiker	2	2	—
Bushbuck	3	3	—
Cane Rats	2	2	—
	61	52	9

In all these cases blood was collected only from old or full-grown game animals exposed to infection over a long period and shot within the high fly density area in the Umfolozi Game Reserve. For each game animal shot, one rat was used. From the 61 rats, nine positive cases were obtained, a carrier percentage of 14·8. All these game animals appeared perfectly healthy on post mortem examination, and were in good condition. Blood and gland smears were taken for microscopical examination from all the game animals used for sub-inoculations into white rats. Of the nine positive biological tests, only one case, that of *T. congolense* in a kudu, was confirmed microscopically. On the other hand, *T. congolense* was diagnosed in a stained blood smear from a kudu which gave a negative biological test in a white rat. Thus of the 61 head of game animals used for biological tests, the presence of parasites was confirmed in two kudu by the direct microscopical examination.

When analysing the results with the 11 kudu used for the biological tests, the microscopical examination of stained smears revealed 18·2 per cent. to have been infected. The biological tests on these 11 kudu increased the percentage to 54·5, and the combined microscopical and biological tests further increased the percentage infection to 63·6. Of the remaining 50 game animals used for biological tests, no parasites were found in stained smears, while biological tests revealed 6 per cent. to have been infected.

The fact that no positive results were obtained from the biological tests on wildebeest, zebra, warthog and other game does not necessarily mean that these samples were not infected.

White rats which are susceptible to the direct transmission of trypanosomes from the bovine, kudu and reedbuck may be refractory to the direct transmission of the same strains of trypanosomes from other species of game such as wildebeest zebra and warthog. This especially appears to be the case with the warthog which, from observations, are known to be favourite hosts of the fly, and parasites were confirmed in stained blood smears taken from warthog.

To observe the effects of potassium citrate on trypanosomes three samples of 10 c.cs. of blood taken from three nagana-infected cattle were collected in three separate bottles, each containing 1 c.c. of a solution of 10 gms. of potassium citrate dissolved in 100 c.cs. of water. After eight hours live trypanosomes were still readily detected in the wet preparations of all three samples. As a control 2 c.cs. of blood from the above samples were injected intraperitoneally into white rats after a period of one hour. Two rats were used, one sample for each rat. In each sample of blood *T. congolense* could be demonstrated as fairly frequent in stained smears. Positive results were obtained from both rats.

Summary

(1) Earlier workers have demonstrated trypanosomes in different species of game in Zululand, both by means of microscopical examination of smears and biological tests. The following species of game have been shown to be carriers:—Buffalo kudu, wildebeest, zebra, reedbuck, impala, bushbuck, warthog, duiker, steenbuck and hyena.

(2) Although a comparatively high percentage of game animals may be suspected of being carriers of trypanosomes in tsetse fly areas, difficulties are experienced in demonstrating the parasites, which are usually present in the game in small numbers only.

(3) With the biological tests, the white rats may not become infected from every sub-inoculation of blood from infected game, while, on the other hand, the white rats may be refractory to the direct transmission of trypanosomes from certain species of game.

(4) Although game animals are injected with the nagana trypanosomes, they have become immune to them so that infected game animals which are carriers of the parasites show no symptoms of being diseased and are in good condition.

Conclusions

By means of the direct microscopical examination of smears from 140 head of game, 5 per cent. were found to be infected. With the biological tests on 61 head of game, 14·8 per cent. were found to be infected, while the combined biological tests

and microscopical examination of smears revealed that 16·4 per cent. of the 61 head of game were carriers. The microscopical examination of smears is not sufficiently reliable to determine the incidence of trypanosomes in game, and it would appear that for the biological tests suitable laboratory or domestic animals should be selected for the different species of game.

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South African Journal of Science, *Vol. XLI, pp. 317-318, February, 1945.*

ALTERNATE ANCHYLOSIS IN THE TEETH OF SOUTH AFRICAN SNAKES.

BY

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Read 4th July, 1944.

Bogert (285 : 1943) has re-directed attention to alternate anchylosis of teeth in snakes a feature which occurrs at some portions of all rows of teeth in *Bitis arietans* Merr., *Naja nigricollis*, *Naja haje*, *Causus rhombatus*, *Psammophis sibilans* and *Python sebae* Gml.

Anchylosis is commoner at the front and back of rows and on the maxilla. Between the anchylosed teeth are teeth in various stages of attachment to the jaw but all in line with the anchylosed teeth. I have noted a site where a tooth was missing without sign of any socket having formed.

Semi-attached teeth are easily displaced but are distinguished from hinder teeth because they have a curvature of their base. The hinder teeth are usually prone and soft, though they are often vertical in *Python sebae* Gml. in which non-venomous snake they probably function.

Few hinder teeth develop dentine and only one row of soft vestigial ones is often visible except in the extreme front end of the jaw where serial arrangement is common, especially in *Bitis arietans* Merr. and *Naja nigricollis* and *Naja haje*, and where their position alone corresponds with functional teeth.

Empty sockets are usually due to dissection where an unattached tooth has been carelessly lost. In nature broken teeth are seldom encountered and once anchylosed loss is impossible without some trace. Extraction of an anchylosed fang means that it has merely been broken off at the base.

Fully mature jaws may be examined through a lens or by the naked eye in the early morning as I have examined many which Mr. Denis FizSimons has kindly given me, applying concentrated Sodium Sulphate solution to any pricks on my fingers. Mr. FizSimons agrees that he has never extracted an anchylosed fang.

Klauber (20 : 1939) has shown that fang-length corresponds with the length of the body in some rattlers and vipers and my measurement of the solid teeth of South African snakes indicates that there is a similar correspondence between the length of the solid teeth and the body length in all snakes.

Britis arietans Merr. with a fifteen millimetre anchylosed fang has a third dentary tooth and a second upper tooth four millimetres long and this is typical of the size of the teeth in other portions of the jaw. Specimens from eighty to ninety millimetres long have many three millimetre teeth.

In one such snake with eighteen millimetre anchylosed fang most of the teeth in the dentary were three millimetres long, the front upper tooth measured four millimetres, the fourteen three millimetre teeth in a row were all anchylosed except three.

Naja have far smaller teeth than Bitis. In *Naja haje* the relation of fang length to body length is reported to be 1 : 292, whilst that of *Naja nigricollis* is 1 : 250. This helps one to judge of a species by measurement of its anchylosed fang, though loss of the tip of a fang must not be overlooked.

A specimen of *Naja nigricollis* from the Victoria Memorial Museum at Salisbury, some seven foot in length had an anchylosed fang with the tip missing measuring seven millimetres, the same length as one of its unattached fangs. The front tooth was one millimetre, the second two millimetres, the third 1·5, the thirteenth 0·5 and all the rest of the right dentary one millimetre. All the teeth of this row, except the eighth, were anchylosed. A seven millimetre fang would suggest that the snake was 1750 mm. in length but with the fang complete it would be from six to seven feet in body length.

Summary.

1. Anchylosis of teeth has been studied in various venomous and non-venomous snakes and note made of the stages of attachment to the jaw of the solid teeth.
2. Alternate anchylosis is seen to be more common in the dentary rows than in the upper and particularly the palatine rows.
3. Examination of the so-called hinder teeth reveals that they are usually soft, that serial arrangement is confined to the front of the jaw and that they do not correspond with the functional teeth.

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NORMALITY IN FUNCTION AND STRUCTURE—THE FOWL

BY

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Onderstepoort.

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In this short paper we deal with the fowl. For our purpose, it is possibly wiser to be humble and state the popular conception of normality. So let us define the normal bird as one that in looks is reasonably characteristic of its breed, that appears to be in good health, and that is producing eggs and meat commensurate with its sex, age, food and general environment. Having said this, we run immediately into a maze of difficulties.

Is it correct to regard a fowl as normal without elucidating its genetic constitution, even though the life of the bird is too short for all its hidden weaknesses to be revealed by appropriate breeding tests? Perfectly normal-looking hens may be heterozygous for defects such as congenital blindness, nakedness and congenital loco, but these unfortunate conditions will not be apparent in the progeny unless the hens are mated to similarly tainted cocks. Since inherited dysfunctions and malformations do not usually go together, it is obvious that a dozen or so special breeding trials would have to be conducted, the mate in each test being a known carrier of a certain defect. Apart from the expense being prohibitive, the fowl would simply die of old age before we had satisfied our curiosity.

Other worries attend our efforts to analyse the genetic make-up of a fowl. Egg production, egg size, shell quality, and the age when the first egg is laid, are all most important expressions of the genetic constitution, yet the mode of inheritance is complex and we can know little of these guides to quality before the progeny is at least a year old. A similar time must elapse before we are reasonably certain that the issue of the union of two normal-looking fowls will not develop a peculiar disease of the bones called osteopetrosis gallinarum.

The greatest scourge confronting the poultry industry is cancer, in all its forms. Though the actual cause generally speaking is still obscure, there is no doubt, whatsoever, that the predisposition to the disease is inherited. This has been proved by the rather crude method of merely mating cocks and hens of twenty months and older, after which age cancer is less likely to kill. In other words, we are always tending to breed from the more resistant members of the flocks. The results certainly

justify the means, but we have no idea at all how the resistance or the susceptibility is inherited. Obviously the mechanism is extremely complicated. Only one example need be cited to illustrate how an apparently wonderful hen can be a menace in the breeding pens. The hen was a perfect specimen of her breed and died in her seventh year, not of cancer, after laying over eleven hundred eggs, which were nearly all fertile and hatched remarkably well. Irrespective of the male to which she was mated, nearly all her chickens died of cancer before they were eighteen months old. Was she a normal bird? Could we have found the hidden weakness without applying the progeny test?

Now let us wander along other bypaths. Crooked keels are well known to all poultrymen, butchers and housewives. What is not appreciated is that the keels would remain straight if the chicks were only not permitted to perch. Crooked keels depend on a combination of two factors—an inherited predisposition plus perching at an early age. Inherently normal chicks can perch with impunity even when younger. Turkeys provide another example of the same sort of thing. When predisposed poults are reared in an arid area noted for lots of sunshine and heat, they develop large, drooping, pendulous crops, whereas others with essentially the same genetic make-up, but raised in a cool, foggy and damp locality, go through life without ever knowing the affliction. Thus we have two perfect illustrations of how an inherited weakness is brought to light by what certainly cannot be regarded as an abnormal environment. We must not blame the environment, but the seemingly normal parents of the birds.

What has been said about the environment is also true of food. A shortage of manganese leads to a deficiency disease called perosis, and rations containing too little riboflavin produce curled toe paralysis. White Leghorns need relatively far less of these substances in their diets than do the heavy breeds such as the Black Australorp. Within each breed, too, there are individuals requiring relatively more manganese and riboflavin than their pen mates. Can we truthfully say a hen is normal, if some of her chicks need far more than usual of a particular vitamin, for them again to develop in an apparently normal manner?

Where bodily structure is concerned, we have to differentiate between some abnormalities and others. The inherited structural defect known as albinism is obnoxious, because the bird with its poorly pigmented eyes cannot cope with the average amount of sunlight. But is a hen necessarily abnormal because she has grown long spurs, even though we object to them from the aesthetic point of view?

If we are still able to think rationally about normal and abnormal fowls, we can carry on with our discussions. A hen

that is a pretty moulter is one that moults slowly. She never looks ragged, and always has a covering of sufficient feathers to enable her to keep warm and take flight from danger. But these fowls are usually poor layers, and the best producers have to walk around, unashamedly, in all their chilly nudity in the late autumn. Which is the normal state here? The poultry farmer will certainly have nothing to do with the naturally normal pretty moulter.

Consider the question of broodiness. A wild bird lays no more eggs than she can cover and then hatches them. To do this she has to go broody, and broodiness depends on inherited factors. Broodiness is tolerated in most breeds of fowls, but certainly not in the White Leghorn. If a Leghorn manifests any maternal instincts, she is promptly denied a place in the breeding pens. It is only right to regard an animal as abnormal if it cannot propagate the species, but is a Leghorn peculiar just because man has chosen to relieve her of one of her fundamental duties, by breeding out the natural instinct and substituting for it a mammoth incubator and electrically-heated brooders? Some more about broodiness. A few figures have been adduced to show that hens without the instinct have a slightly shorter expectation of life than their sisters that go broody. If this is definitely the case, then a lack of the desire to sit must be regarded as an undesirable, if still profitable, abnormality.

A hen harbouring the germs of bacillary white diarrhoea in her ovary must be regarded as abnormal, no matter how healthy she may look and how well she may lay. In the U.S.A. they have bred two strains of chicks, the one reasonably resistant to B.W.D. and the other susceptible. Are we to regard the mothers of the former as being more normal, if the term may be used, than the dams of the latter? Presumably, resistance to infection is a desirable and hence normal characteristic. No breeder will contemplate dispassionately the possibility of any undesirable feature being normal.

When hens recover from spirochaetosis, a blood disease transmitted by tampans, they are immune, and have the faculty of transmitting this immunity through their eggs to their offspring. The chick's resistance is evanescent, but it certainly protects the bird against a fatal attack of the disease while it lasts. It is doubtful if such an immune chick can be regarded as being more normal, any more than fowls immunised against chickenpox can be considered more normal than their susceptible fellows. Only when there is a resistance to disease, of true genetic origin, can we legitimately claim a greater degree of normality for the hardier stock.

Finally, we must think of the vast number of animals that are carriers of dangerous infective agents, without suffering in any way themselves. They look and function like so-called

normal animals, although they are a constant menace to their fellow-creatures. Epidemiologists, at least, would hotly reject any plea to have carriers classed as normal. In the avian world we encounter carriers of the causal agents of fowl malaria, psittacosis, infectious bronchitis, hexamitiasis, histomoniasis and infectious laryngotracheitis, and these are only a few of the most important diseases that might be named.

This very brief discussion can do no more than help to set minds thinking about normality in structure and in function. It is perhaps possible to state what exactly is meant by a normal bird, but since no such creature has ever been known or is likely to be evolved, we may as well spare ourselves the mental effort. Besides, should there be the slightest chance of breeding the near perfect fowl, the scientist, as the earthly arbiter in such matters, would immediately succumb to his natural temptation to raise the standard a wee bit higher—just enough to present a new challenge to his unbounded conceit—and we would be confronted again with the question: What is a normal hen? No, let us rather be realists and generally take our cue from the layman, who has at least a working knowledge of what is normal. One thing, however, is clear. No doctor or veterinarian can ever hope to appreciate fully the significance of various pathological states, without having a most intimate knowledge of so-called normal function and structure. Conversely, a true appreciation of the accepted normal cannot be gained, without studying carefully the various aberrations that may arise.

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NORMALITY FROM THE STATISTICIAN'S POINT OF VIEW

BY

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With 1 Text Figure.

Read 4th July, 1944.

Whatever the deeper significance of the word " normality " may be, it is clear that, it it were possible to assign a numerical quantity to each scientist's interpretation of this word, these quantities would not obey the " normal " distribution of the statistician. What " normality " implies seems to be obvious to everyone, and yet, as soon as an attempt is made to tie the term down to something more definite, serious dissension ensues. Now, keeping in mind Whitehead's dictum that it requires a very unusual mind to undertake the analysis of the obvious, let us attempt to investigate how far statistics can supply the conceptual material for the biologist to utilize in the construction of a satisfactory definition of normality, be it of form, function or both.

In doing this we must, however, be quite clear as to how statistics and its adjuncts are related to the realm of the biological sciences. On this point there seems to be more confusion than on normality itself. Theoretical statistics, by its very definition, is solely concerned with the construction of conceptual models, the inter-relating of these models, and the critical testing for logical consistency. Applied statistics on the other hand, has for its purpose the application of the consequences of these theoretical constructs to practical data, and is mainly concerned in finding suitable methods for their application. Finally, Experimentology aims at providing a calculus which will bridge the gap between the conceptual models of the so-called exact sciences and perceptual phenomena in biology. It will guide biological research on the basis of existing knowledge, and adjust existing theories on the basis of new experimental facts, found in a valid way. Once these distinctions are clear in the mind of the biologist, it will no longer be necessary to allege that certain people use statistics as a drunkard does a lamp-post—more for support than illumination

From the conceptual point of view of the statistician, the definition of normality need cause no difficulty. There are, however, at least two essential prerequisites:—

(1) Normality in the statistical sense refers only to numerical quantities.

(2) The concept of normality is built up on the principles of "more than one." In other words, the unique cannot be treated by any statistical methodology.

It must be clearly recognised that although we are concerned with the study of more than one individual, any aggregate derives its significance from the manner in which these individuals are combined to form a group, or system of groups. From a classificatory point of view, there exists thus a very intimate relationship between the individual and the group to which it belongs. If this relationship is of a certain prescribed nature, then we speak of a statistical population. The desideratum for a collection of figures to form a statistical population is that the relative frequencies of deviations of the individual values from some central value, should conform to some law of probability or chance, expressible in the form of a mathematical equation.

There are many possible types of probability laws, defining different statistical populations; one of the simplest is the so-called "normal" distribution. This expression is characterized by only two parameters, i.e., two quantities summarizing all the relevant information:

(a) the arithmetic mean, representing the average value of the population;

(b) the variance, which represents the average dispersion or "spread" of the individual values around the arithmetic mean.

The pictorial representation of this law is characterized by its bell-shaped form: most values lie around the mean and the curve tails off rather rapidly on both sides. The appended graph shows all the pertinent details.

Conceptual Model of Normality:

$$dF = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\xi)^2}{2\sigma^2}} dx$$

Can criteria for the normality of observed data be established from this conceptual model? To take an example, suppose that past experience has shown that individual estimates of yeast growth in a standard medium are essentially normally distributed, with a mean yield of 90 milligrams and a standard-deviation (the square root of the variance) of 10 milligrams.

Consider then the following data, which represents milligrams of yeast produced in medium A. (1).

Medium A.		
	100	
	110	
	85	Normal population mean = 90 mg.
	90	Standard deviation ... ... = 10 mg.
	93	
Total	478	
Mean	95·6	

Are the observed values consistent with the hypothesis that medium A is equivalent to the standard medium? Or, put in another way, is the difference of 5.6 significant or just due to chance? We first decide on a criterion for normality: if this difference exceeds twice its standard-deviation, then it will be regarded as significant.

Without giving the computational details, we find twice the standard-deviation of the difference equal to 8.9. Since our difference is only 5.6, we conclude that our sample is " normal " and that, on this basis, medium A is equivalent to the standard medium. (It must be stated that the criterion used is rather of the rule of thumb type, but the example serves to illustrate the main idea of such a test.)

Although the normal curve was developed by Abraham de Moivre as early as 1733, it was not applied to biological and social phenomena until the end of the nineteenth century, when Lambert Quetelet and Francis Galton were impressed by the way their data seemed to conform to this curve. Galton, for instance, wrote:

> " The law would have been personified by the Greeks and deified, if they had known of it. It reigns with serenity and in complete self-effacement amidst the wildest confusion. The huger the mob, and the greater the apparent anarchy, the more perfect is its sway. It is the supreme law of Unreason "(2).

No wonder that biologists of this period believed that this curve was an ideal to which most biological distributions ought to conform, and, as a consequence, the expression " normal " law took root. This enthusiasm abated a little when Karl Pearson and others developed a more general system of frequency curves, which showed that in biological measurements the normal distribution was the exception, rather than the rule.

Soon after the beginning of the present century, a change in emphasis on the whole question of normality or non-normality became evident. This was the result on the one hand, of a more intensive method of biological experimentation, and, on the other hand, of extremely important results in theoretical

statistics which established a closer co-ordination between the method of experimentation and the critical evaluation of the data. Once again, from a statistical point of view, the normal curve was re-instituted, this time, however, not as a " supreme law of Unreason," but merely as a mathematical artifice to assist in the construction of the theory of small samples. This theory, with which the names of W. S. Gosset (" Student ") and R. A. Fisher are especially associated, is mainly concerned in deriving significance tests based, not on the normal distribution as such, but rather on the so-called sampling distributions of statistical coefficients, taking into account the limited number of observations available in biological experiments. It thus supplies, if appropriate to the phenomenon under study, a powerful basis of induction.

In the above example our criterion of normality consisted in accepting those values as normal, which lie within a pre-assigned range of the mean value. We utilized past experience in assisting us with the application of this criterion. Usually, however, in biological research we have very little past experience of the phenomenon under study. Because of this lack of information, the mentioned change in emphasis occurred. Small-sample theory attempts to take this limitation into account, and very extensive techniques have been developed. As is natural to expect, this methodology will only be valid for applicational purposes, in a range determined by the axioms and assumptions of the theory.

The nature of these limitations has not been clearly understood by everyone, with the result that indiscriminate application of statistical methods often has led to extreme vagueness or even absurdity of interpretation.

This difficulty is due to the fact that all statistical concepts are, and must be, artificial in the sense of being constructs of the human mind. Only when the conditions determining the data are of such a nature, that they agree with the assumptions on which statistical theories are based, can a really valid interpretation be made.

In very recent years this necessity has been felt very strongly in certain statistical circles, with the result that the school led by J. Neyman and Egon Pearson, are investigating, from a mathematical point of view, the validity of drawing conclusions by small-sample theory. Experimentologists again, believing with Descartes that " La Méthode crée les resultats," are investigating how the experiment, as the only scientific method of " learning by experience," should be planned so that the desired result can be validly obtained by the use of the appropriate conceptual model. In this problem of planning special emphasis is laid upon the basic importance of selecting a measurement, really appropriate to the phenomenon under

investigation. Indeed, if this basic requirement is not met, it seems a waste of time to apply refined methods of evaluating a priori useless data.

How now does all this information affect the subject of our paper? We can succintly summarise the results obtained, as follows:

(1) Normality is a philosophic concept and not a natural phenomenon.

(2) Statisticians have constructed a theoretical model of normality which, under prescribed conditions, has a utilitarian value.

(3) These prescribed conditions can only be realised in an experiment by the full and equal co-operation of biologist and statistician.

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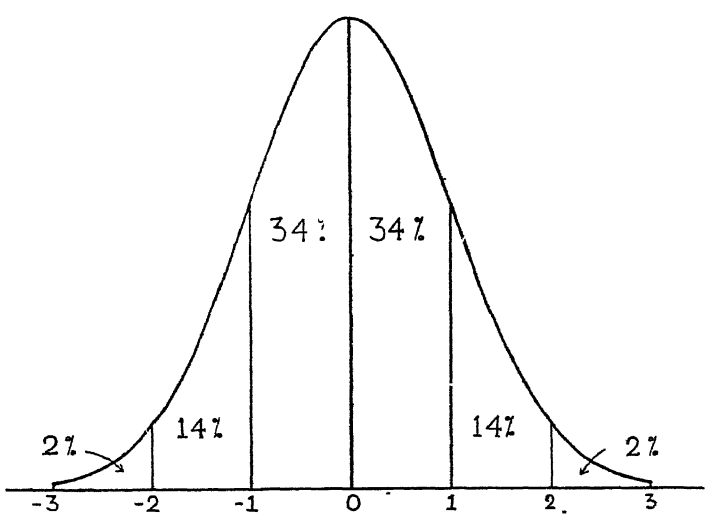
STATISTICAL MODEL OF NORMALITY.

Areas represent number of individuals, Abscissa unit is one standard deviation.



Law of Normal Distribution.

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THE CELL MASSES IN THE FOREBRAIN OF THE ELEPHANT SHREW

BY

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Read 4th July, 1944.

(Abstract).

1. All the subcortical olfactory centres of the elephant shrew (*Elephantulus myurus jamesoni*) resemble those in marsupials (Opossum, Caenolestes and Arolestes) and in edentates (*Tamandua tetradactyla* and *Orycteropus afer*).

This resemblance is found in the anterior olfactory nucleus, the septum, preoptic region, amygdala and olfactory tubercle.

2. The amygdala possesses a basal accessory nucleus, which is a feature of similarity between Elephantulus, marsupials and edentates and apparently a character entirely confined to these three mammalian groups.

3. The pyriform cortex and neopallium of Elephantulus are very primitive. The primitive character of the neopallium is chiefly evidenced by the very few layers of cells composing it. Its extensive surface area is no indication of advanced development, for it has been stretched out by the underlying hippocampal formations. The pyriform cortex is relatively extensive and is divided posteriorly into two gyri by a prominent longitudinal fissure. Such a division of the pyriform cortex is another feature confined to Elephantulus and the marsupials.

4. The hippocampal cortex is at least as extensive as either the neopallium or the pyriform cortex. This large area of hippocampal cortex is a specialised feature seen in all insectivore brains, but it has been developed to a more marked degree in Elephantulus than in any other insectivore.

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PREHISTORIC ROCK ENGRAVINGS IN THE KRUGERSDORP-RUSTENBURG AREA OF THE TRANSVAAL

BY

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With 8 Text Figures.

Read 3rd July, 1944.

Over 300 properties that contain rock-engravings had been recorded in South Africa at the outbreak of the present war. Of these, just over 70 are in the Transvaal, 10 of which are in the districts of Rustenburg and Krugersdorp (van Riet Lowe, 1941). New sites are, however, continually being added to the list. Three of the latest discoveries demand special notice, for they are the only sites known to contain pure line-engravings only. Although this form of engraving has been repeatedly noted in various parts of South Africa, it has always occurred with the more common rock-peckings which often appear superimposed on the line engravings (van Riet Lowe, 1937).

As may be seen from the accompanying illustrations, the engravings are undoubtedly among the most beautiful and skilful that have ever been discovered. As drawings they reached artistic heights that were seldom, if ever, surpassed in prehistoric times. They certainly represent the climax of artistic achievement in prehistoric art in South Africa, and are rivalled only by the finest rock paintings of the best polychrome period—the Abbé Breuil's " Period of the Eland," when Stone Age artists held complete sway over the sub-continent. Their art is restful, and suggests a life of peace and possibly of plenty. The southward movement of Bantu-speaking people had not yet reached the areas over which they held sway; and life was as undisturbed as it could be among these simple, primitive hunters. The absence of such discord as was introduced into their country when the black wave of Bantu-speaking people swept over it from the north is well reflected in the restful harmony and essential simplicity of their art.

Apart from their intrinsic value and appeal as works of art, the most striking feature of these engravings is the fact that there are no wrong or duplicated lines and no attempts to " rub out " or alter. The artist revealed neither hesitancy nor uncertainty in his touch. The strength and simplicity of his draughtsmanship reveal qualities which are only to be sought

in the most gifted and talented artist. This striking certainty of touch and unusually fine draughtsmanship have at times led me to suspect that the figures may first have been drawn in some such substance as charcoal, and that the engraver then followed the lines with whatever engraving tool he used. But this may be an insult to an artist whom I wish neither to insult nor to underestimate, for there can be no doubt that whatever technique he employed, he was not only an unusually gifted draughtsman but also a skilful craftsman.

My illustrations of his work have been executed to the best of my ability, but they must be regarded as interpretations rather than as facsimiles in miniature. They are intended merely to convey an impression. The originals must be seen to be appreciated, not only for scale but also for effect. Fortunately, all the specimens chosen for illustration are in the museum of the Archaeological Survey in Johannesburg, and may therefore be easily seen. The process adopted for reproduction was: (i) rubbings were made from the originals, (ii) these rubbings were then traced, and (iii) the tracings were reduced in the process of reproduction. The human element is thus reduced to a minimum, the only chance of error being in the tracing process. This method was chosen in preference to direct photography (a) to keep the cost of printing down, and (b) to get as accurate miniatures as possible. While I am satisfied with the accuracy of the reproductions, I repeat that they are intended merely to convey an impression, and that I shall be happy to show the originals to all who are interested.

The three sites to which I have referred lie in the *Groot Moot* near the western limit of its hundred-mile stretch immediately south of the Magaliesberg. They are on the farms Commissiedrift No. 300, near Olifantsnek, about 10 miles south of and in the district of Rustenburg, and on the adjacent farms Doornkloof No. 103 and Doornhoek No. 117 near the Maanhaarrand store about seven miles north of Magaliesburg station, in the district of Krugersdorp. The distance between the Rustenburg and Krugersdorp sites is about 20 miles.

The geology of the area is important. It is characterised by steep-dipping quartzites and shales of the Transvaal System (which is most prominent in the Magaliesberg Mountains), with intrusive diabase in the form of dykes, the most prominent of which is the long, narrow ridge known characteristically as the Maanhaarrand. These igneous intrusions have altered the adjacent shales to hornfels which has weathered into large rounded boulders that now lie scattered on the hillsides in the immediate vicinity of the intrusions. Although not as fine-grained as its fellow indurated shale, lydianite, this hornfels is the only rock which lends itself to the engraver's art in the neighbourhood. It is a fine-grained and compact rock which, as a result of weathering, has acquired a comparatively smooth

reddish-brown crust that undoubtedly attracted the engraver's attention—just as it was attracted by the fine surfaces that one so frequently sees in the more southerly areas where we have extensive outcrops of Ventersdorp diabase in the south-western Transvaal and Griqualand West — occasionally as glaciated pavements or *roche moutonnée* as at Nooitgedacht and Driekops Eiland near Kimberley—and Karroo dolerite in the Orange Free State and Cape. The vast majority of rock peckings and engravings that have hitherto been discovered occur on these comparatively smooth diabasic and highly metamorphosed rocks, but the fact that we also have engravings on certain softer rocks, such as the G-Stone of Gestoptefontein near Ottosdal (van Riet Lowe, 1937) and sandstone such as we find at Vereeniging shows that our prehistoric engravers did not confine themselves to hard rocks. Possibly their work on the softer rocks ha weathered away—especially where the surface of the rock prevented a rapid escape of water—so that with rare exceptions only the engravings on the harder rocks have survived exposure to the elements. Be that as it may, the Magaliesberg occurrences are peculiarly interesting in that as a group they are unique not only from a technical point of view but also from an artistic. The least that can be said of them is that, unlike the majority of petroglyphs which have been described as engravings but which are in reality pecked or stippled figures, most often without a single engraved or incised line, these Magaliesberg occurrences are engravings in the literal and true sense of the word.

The Magaliesberg hornfels—actually a cordierite hornfels—has an unusually thin crust over its natural blue-grey interior. This crest or naturally weathered surface seldom exceeds a millimetre in depth, and it can easily be cut by a suitable stone graving tool. When an incision in excess of a millimetre in depth is made, the blue-grey " living rock " of the interior is exposed. This enabled the artist to achieve the pleasing effect of a blue sketch on a brown canvas.

The illustrations reveal four—possibly five—types of engravings: (1) very finely engraved geometric designs (2) finely engraved animal profiles, (3) smoothly rubbed and polished silhouette with finely engraved profile, (4) grooved profile, and ? (5) possibly painted silhouette with finely engraved profile. With the exception of the geometric designs reproduced in Fig. 1 and the group shown in Fig. 4, all the sketches are of single animals: elephant, rhinoceros, buffalo, wildebeest, lion, eland, kudu, sable and other antelopes and jakhal. The patina within the engraved lines is indistinguishable from that without. This patination or weathering does not necessarily indicate great age, but when it is realised that in several cases the rock surface that contained engravings has itself weathered away and has taken portions of the engravings with it, we are entitled to attach an appreciable age to the engravings.

1. *Geometric Designs.*—Three are shown in Fig. 1. In these the engraved lines are about 0·1 mm. in breadth and 0·1 mm. in depth. Unless the incidence of light is favourable, it is quite impossible to detect the engraving whether one looks at the rock in- or out-of-doors. At Gestoptefontein and elsewhere these very finely engraved geometric designs, invariably cross-hatched, occur *under* the line-engraved animal profiles and are, so far as we know, the oldest rock engravings in the Union. They should be compared with the hair line engravings listed under my Series I.A. at Gestoptefontein (1937). Among these geometric designs we find what appear to be stylised human figures.

2. *Finely Engraved Profiles.*—The kudu shown in Fig. 2 is particularly interesting not only as a fine line-engraving, but rather on account of the expert manner in which the engraver adapted his figure to the triangular rock he chose for his surface. The outline of the rock is shown by the broken line. The artist solved the problem of sketching the kudu on this awkwardly shaped " canvas " by depicting the animal in a loping attitude. Nowhere do the engraved lines measure more than 1 mm. in breadth and more than 1 mm. in depth.

In Fig. 3 we have an equally finely engraved rhinoceros and in Fig. 4 a group of sable antelope—the only known attempt at grouping..

Fig. 5 includes two particularly delicate and striking studies. In both these sketches the engraved lines measure less than ½ mm. in width and ½ mm. in depth.

The engravings in Figs. 2, 3, 4 and 5 should be compared with those listed under my Series I.B at Gestoptefontein (cf. Fig. 1, p. 256. Ref. 1937).

3. *Smoothly rubbed and polished silhouette with finely engraved profile.*—The wildebeest reproduced in Fig. 6 is among the most interesting engravings in the area. So far as I am aware, it is unique. The entire silhouette has been very finely rubbed and polished to a smooth surface, and the incised lines that encompass it are as delicate as are those of Fig. 5. It has unfortunately been slightly damaged by vandals in recent years Oddly enough, the recent superficial scratches do not appear in rubbings, casts or moulds.

4. *Grooved Profile.*—The engraving reproduced in Fig. 7 is one of two in which the engraved lines of the profile were widened into grooves that are about 2 mm. in width and, in places, over 1 mm. in depth. The grooves are smooth and concave, and were apparently obtained by rubbing a narrow, blunt tool up and down the original engraved lines. Both these grooved engravings are of eland.

With the exception of the rhinoceros shown in Fig. 3 and the horse and hippopotamus in Fig. 8, all the figures selected for illustration are from the farm Doornkloof No. 103.

5. *Painted Engravings.*—In certain light, the rock surface enclosed by the engraved line of some of the figures appears to differ from the natural rock surface that surrounds them. This has led some competent judges to suspect that some of the engravings may have been painted and that the colour differences within and without the outlines of the figures referred to are due to the chemical effect of the paint on the rock. As no trace of paint has yet been detected, and as the colour differences are not seen by all, the suspicion must necessarily remain a suspicion. In passing, however, it is interesting to recall that Goodwin suspected something similar at Vosberg (Goodwin, 1936).

6. *General.*—There is no reason to suspect any differences in age between the types of engravings listed under paragraphs 2, 3, 4 and 5 above. Patina provides no clue. We are therefore entitled to assume that these animal engravings represent a single phase in the cultural, and therefore artistic, development of man. A purely artistic analysis strengthens the assumption. In addition, not one of these new sites includes a palimpsest, so that we are unable to detect any differences in age between the various styles and techniques. On other sites, however, we find the line-engraved animal profiles superimposed on the more finely engraved geometrical figures (1937). This entitles us to attach a greater age to the latter, and therefore to suspect that they are older in this area; yet we cannot say whether the difference in age is to be gauged in minutes or in millennia. All we can say with certainty is that in South Africa we have evidence that geometrical figures were engraved by man before he engraved animal figures, and that these line-engraved figures are older than the more common " engravings " where the technique employed by the artist was a pecking or stippling process.

Conclusions

It is inconceivable that these three new sites are the only ones that contain nothing but pure line engravings; there must surely be more—possibly many more, and it is sincerely hoped that this contribution will stimulate further search and thus ultimately give rise to a more complete record of sites that undoubtedly contain some of the most interesting and perfect prehistoric works of art in South Africa.

Where the lines are as delicate as are those in the originals of Figs. 1 to 6 and 8, engravings are often very difficult to detect. Detection depends on the incidence of light. The best hours for field work are when the sun is low—in the early morning or toward sunset. The fore-shortened engraving of the hippopotamus illustrated in Fig. 8 is from the farm Stowlands-on-Vaal No. 719, on the left bank of the Vaal immediately opposite Christiana, in the district of Boshof, O.F.S. I have included it here because it is on a very well-known hill on which hundreds of rock peckings occur. For over a quarter of a century

the owner, Mr. J. C. Philipson-Stow, has guarded and taken a deep interest in the occurrences. He has mapped the hill and numbered and plotted the position of each figure, yet after a quarter of a century of familiarity with the occurrences he never saw the engraving until I recently revisited the hill with him late one afternoon and saw it quite by chance in the rays of a setting sun. It is on a flat rock on which Mr. Stow had often sat or which he had used as a "desk"; but he never happened to make use of it under a rising or a late setting sun, and so year after year he missed the only known genuine line-engraving on the site.

Mr. W. Fowler, of Koffiefontein, to whom we owe so much in the archaeological and palaeontological fields, has had similar experiences. I well recall an incident when in 1928 I took Mr. Miles Burkitt to see the engravings on the farm Afvallingskop near Koffiefontein (Burkitt, 1928). After some hours of work we selected a flat rock on which to rest and enjoy our evening tea before returning to the village, when a sudden "Look!" drew our attention to the figure of a finely engraved horse (Fig. 8) on which someone had put a thermos flask. Both Mr. Fowler and I had paid repeated visits to the hill, and although we thought our searches had been exhaustive, the rays of the setting sun suddenly revealed the horse, which had until then been passed unnoticed—and I, at least, had almost certainly sat on it on a previous occasion!

I have mentioned these difficulties merely to emphasise the need to select the early mornings and late afternoons for search after such fine engravings. Unless one has great luck, one is extremely unlikely to see them at other times.

In conclusion, I have regretfully to record the fact that on not one of the sites here described have we yet discovered a single stone implement—despite the fact that the Abbé Breuil, Mr. B. D. Malan and I made a joint and thorough, though confessedly superficial, examination of the Doornkloof site. The Commissiedrift *area*, on the other hand, is comparatively rich in remains, none of which can, however, be associated with the engravings in the sense that we are able to say that the engraver made and used this, that, or the other implement.

The question of associating stone implements with engravings is an unusually difficult one. Possibly we shall never solve it satisfactorily, but it is interesting to note that line-engravings such as I have described are not only among the oldest types of petroglyph known, but are possibly among the oldest forms of art in South Africa. When superpositions occur, the engraved lines consistently appear under the pecked figures. Goodwin has recorded a striking case at Vosberg (1936), and I have recorded others elsewhere (1933, 1937). Where I have been inclined to place this art at the beginning of the Later Stone Age (1928), Goodwin is inclined to associate it with an advanced expression

of the Middle Stone Age; and in this inclination—for inclination is all it is—he is supported by the Abbé Breuil. In other words, it is possible that the earliest art in South Africa was enjoyed by people whose material culture is characterised by flake industries which are based on the most fully developed Levallois technique and not on any blade industry that characterises the Later Stone Age.

At Vosberg, Goodwin associates the earliest engravings with the Vosberg industry—an industry which he, in turn, relates to the Alexandersfontein variation of the Middle Stone Age. At both the classic Stowlands-on-Vaal site—on which the original of the hippopotamus reproduced in Fig. 8 may be seen—and the very important Bosworth site near Klerksdorp (1937), there is an abundance of Middlé Stone Age remains. Similarly, the engraved area on the farm Klippiespan near Kimberley, but in the district of Boshof, O.F.S., has yielded only Middle Stone Age remains; but I can list an equal, indeed a greater, number of other engraved sites that have yielded only Later Stone Age remains, and so the question must remain an open one until we have more satisfactory evidence of association than we have at present It is, however, important to note that while gravers are not uncommon in certain Middle Stone Age assemblages they are decidedly uncommon in the Later Stone Age. They occur in greatest abundance in areas which are not known to include rock engravings; indeed, they occur in abundance in areas in which such engravings could not have been made, simply because there are no suitable rock surfaces in these areas. The final difficulty is the recognition of the tool used for engraving. We cannot be certain that any graver we have was used in this way. There is, therefore, still scope for considerable research in this field.

ACKNOWLEDGMENTS

I am indebted to Mr. A. B. and the late Mr. E. Sunner, who first drew my attention to these pure line-engraved sites, and who liberally presented to the Archaeological Survey the group of engravings that had to be removed during building operations on their property Commissiedrift, near Rustenburg. I am also grateful to Mr. P. Roux, a teacher of Turfgrond, who discovered and first took Mr. B. D. Malan of my staff to the Doornkloof site; as well as to the owner of the farm, Mr. P. J. Pistorius, who permitted the removal of the engravings that were among those being damaged and destroyed. I am also indebted to Mr. H L. Scott, of the staff of the Kafferskraal School, near Zeerust, who, when he discovered the value of these engravings, presented a fine specimen he had removed from the Rustenburg site many years ago; and finally I am indebted to Prof. John Phillips, of the Department of Botany at the University of the Witwatersrand, for having generously provided special transport to enable me personally to visit the Doornkloof site to supervise

the removal of the engravings Mr. Pistorius felt should be removed for safekeeping in the museum of the Archaeological Survey.

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INDEX TO ILLUSTRATIONS.

Fig. 1.—Very finely engraved Geometric Designs from the Farm Doornkloof No. 103, dist. Krugersdorp, Transvaal.

Fig. 2.—A finely engraved profile of a kudu from Doornkloof No. 103, dist. Krugersdorp, Transvaal.

Fig. 3.—A finely engraved profile of a rhinoceros from Doornkloof No. 103, dist. Krugersdorp, Transvaal.

Fig. 4.—The only known attempt at grouping. Finely engraved profiles of sable antelope—suspected of having been painted—from the farm Doornkloof No. 103, dist. Krugersdorp, Transvaal.

Fig. 5.—Finely engraved profiles of steenbok and jakhal from Doornkloof No. 103, dist. Krugersdorp, Transvaal.

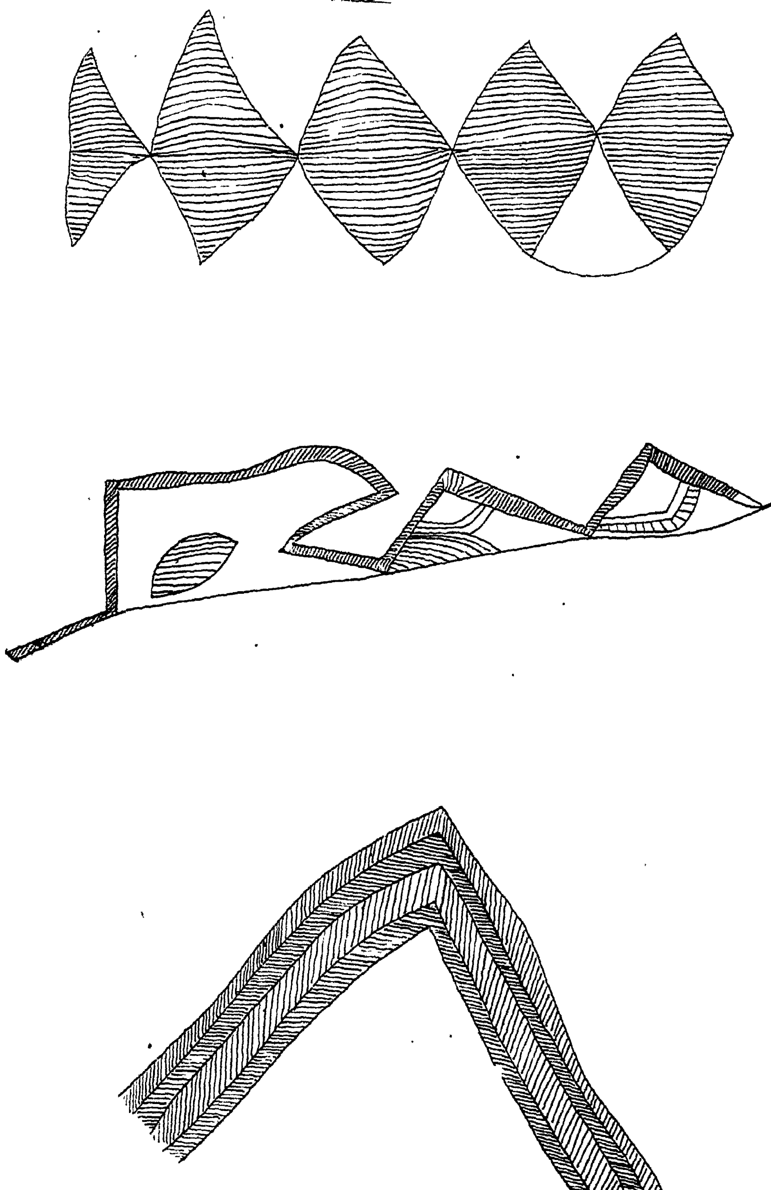
Fig. 6.—Rubbed and smoothed silhouette of a wildebeest with finely engraved profile from Doornkloof No. 103, dist. Krugersdorp, Transvaal.

Fig. 7.—Grooved profile of eland from Doornkloof No. 103, dist. Krugersdorp, Transvaal.

Fig. 8.—*Upper figure:* Very finely engraved profile of hippopotamus from the farm Stowlands-on-Vaal No. 719, dist. Boshof, Orange Free State. *Lower figure:* Very finely engraved profile of zebra from the farm Afvallingskop No. 182, dist. Koffiefontein, Orange Free State.

Note: The scale of the above figures is as follows:—Figure 1, one-third that of the Rock Engraving; Figure 2, one-fifth; Figure 3, one-third; Figure 4, one-fourth; Figure 5, Steenbok, one-half; Jackal, one-third; Figure 6, one-half; Figure 7, one-fourth; Figure 8, one-third.

FIG. I



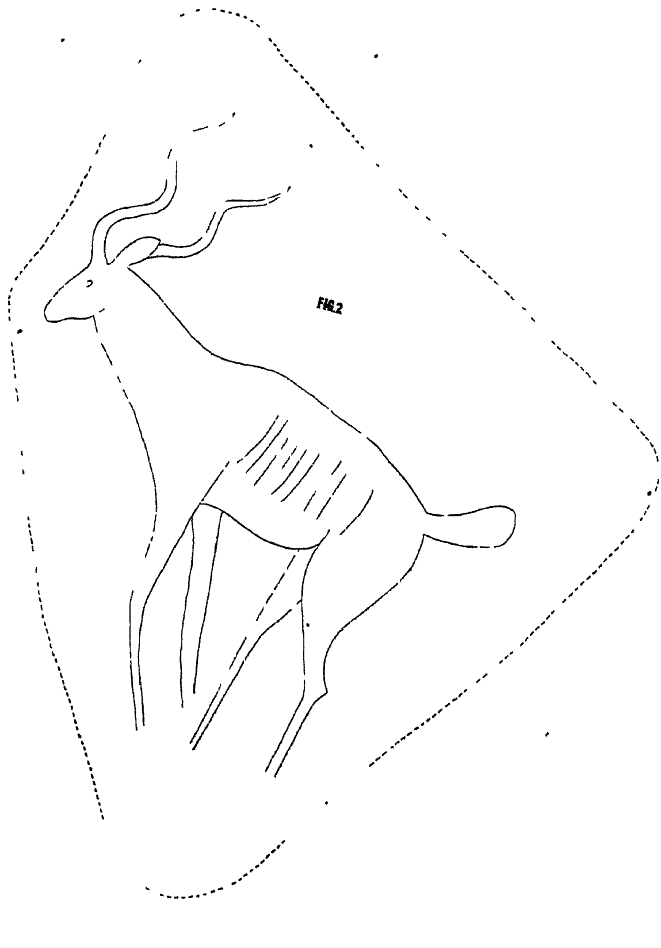
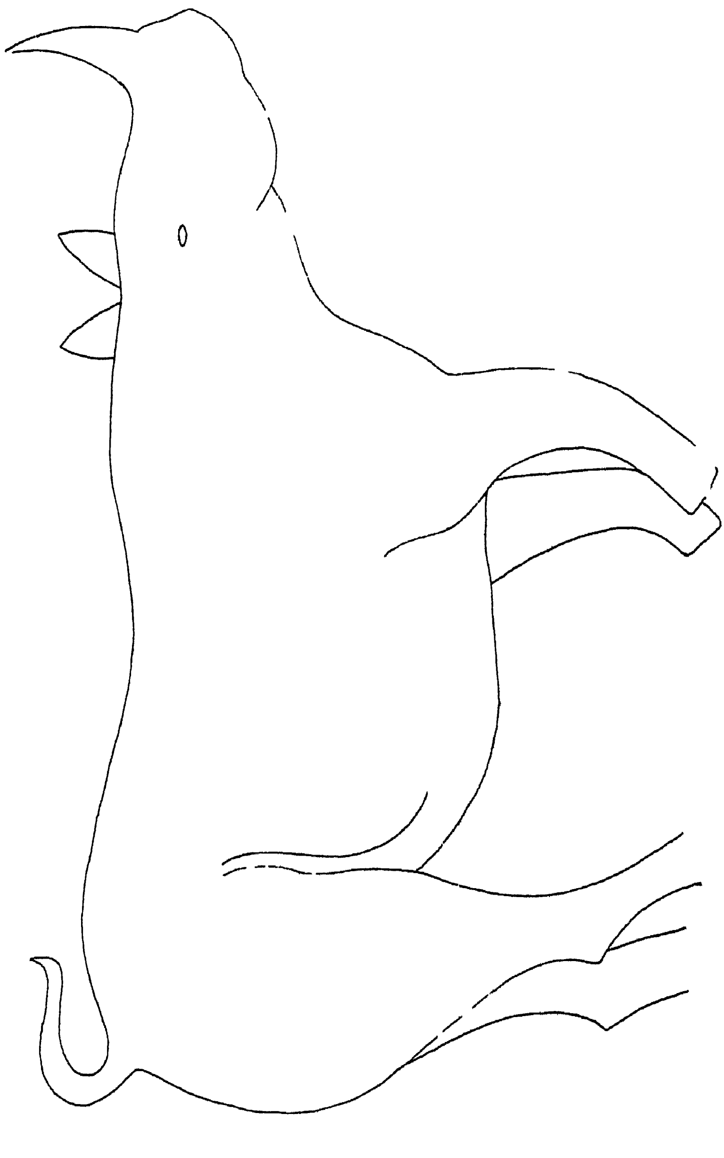


FIG.2

FIG.3



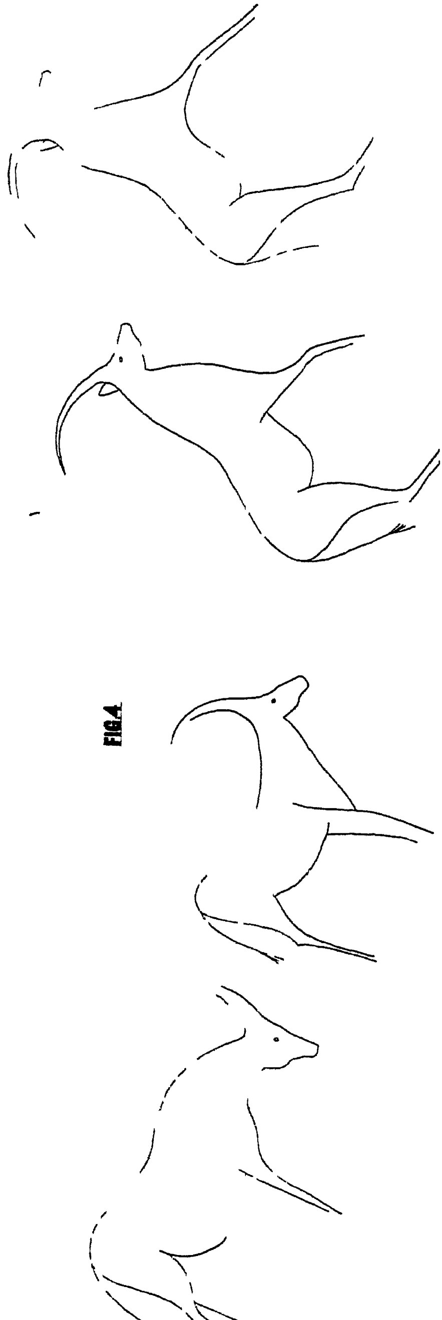
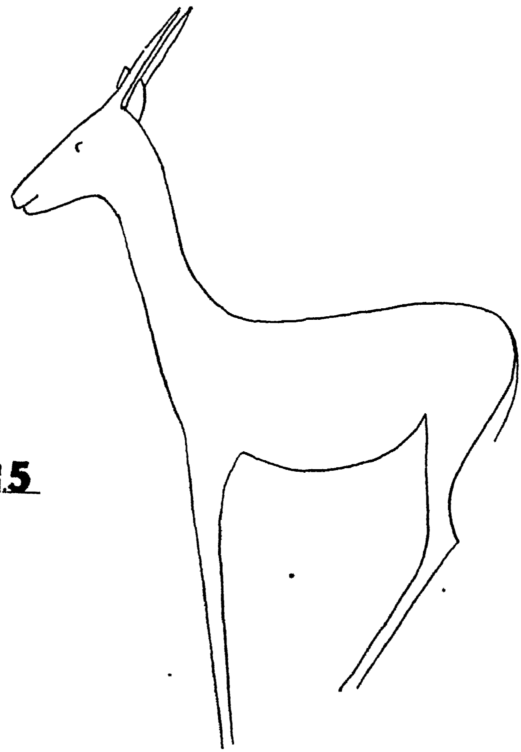
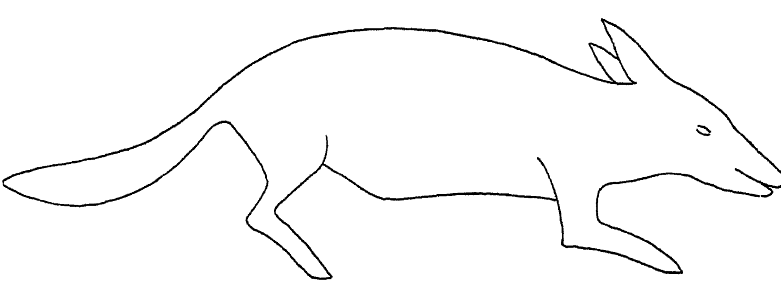


FIG. 4

FIG.5





G.6

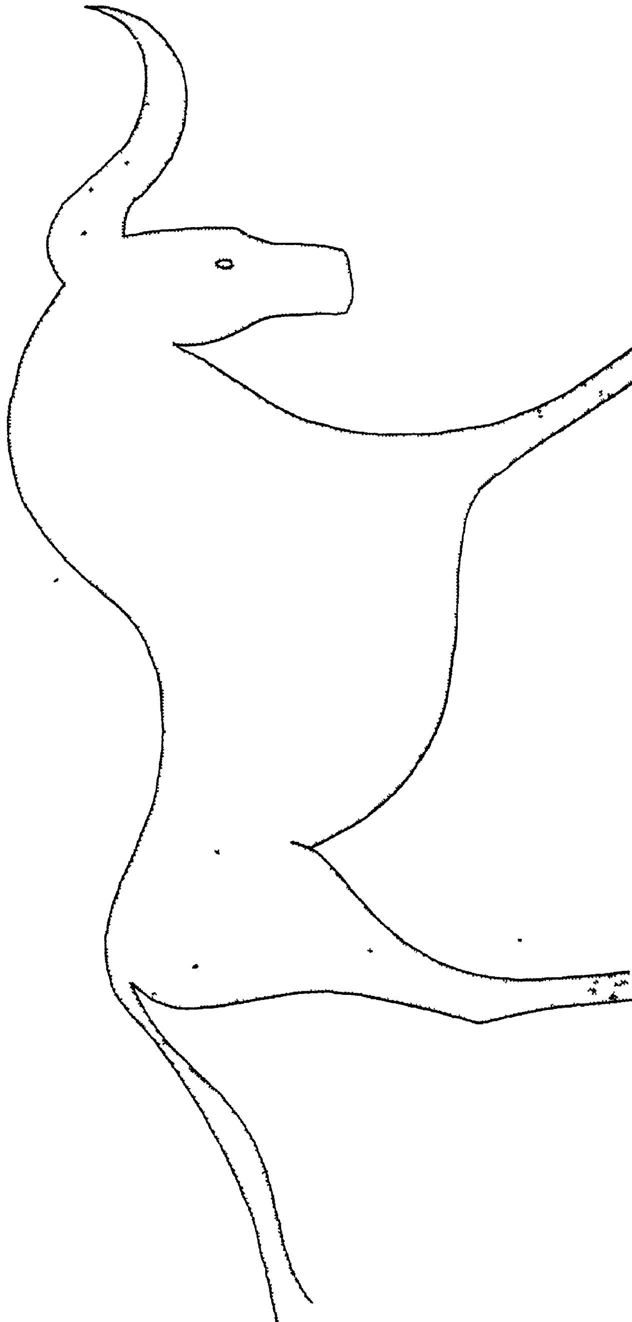


FIG. 7

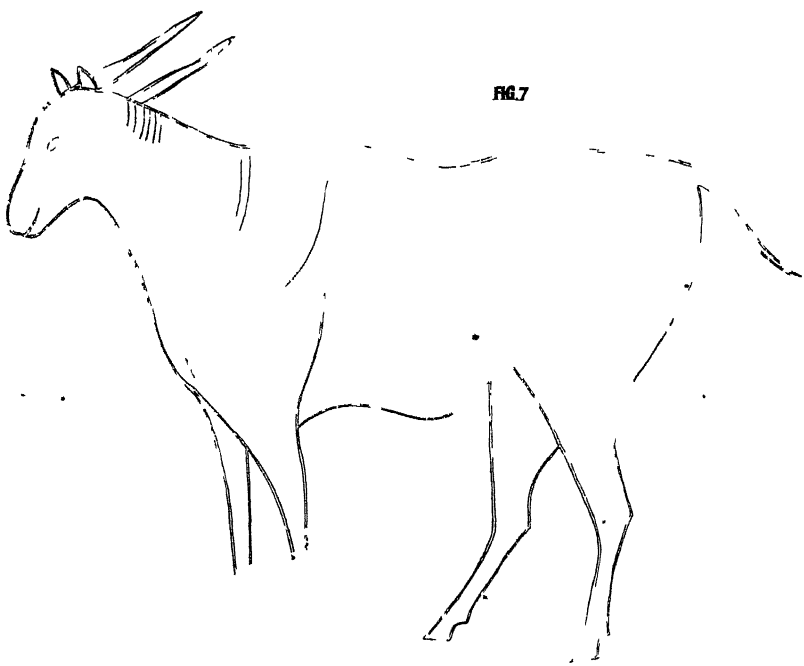
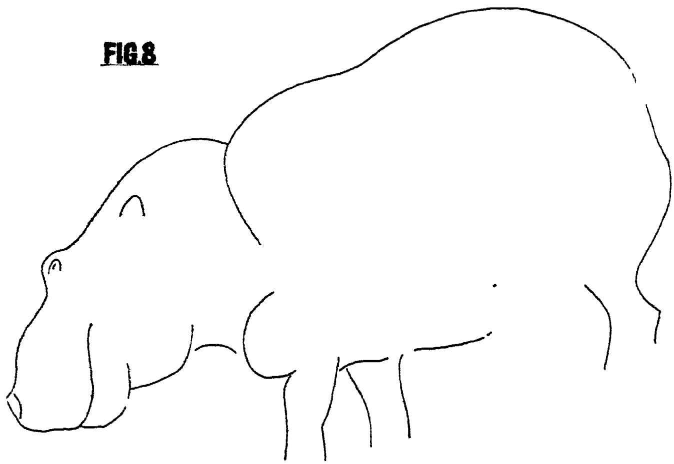
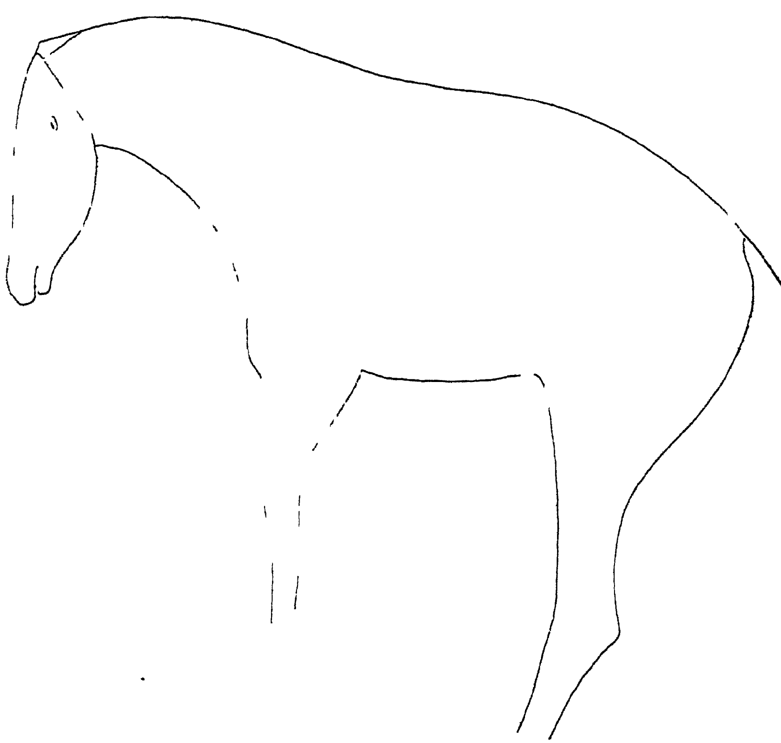


FIG. 8





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PITFALLS IN PREHISTORY

BY

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Read 3rd July, 1944.

I have been repeatedly asked to record a few of the more picturesque pitfalls or potential pitfalls I have encountered in my field work. In attempting to do so, I have selected examples which, although they deal with entirely recent events, reflect the kind of thing that has undoubtedly gone on in one form or another from time immemorial. Where they have no direct bearing on prehistory, they have a bearing on the general background of all archæological fieldwork. Their picturesqueness neither hides, nor does it dull, the lessons they contain; rather the opposite, for the warnings within them need to be taken into account by all who work in the field. In some, the value is psychological as much as archæological.

There is little in prehistory which provides a greater problem than that which the Abbé Breuil calls a " travelling piece "—that is a piece collected on one site and deliberately transported to another. We have repeatedly found that men who lived on or near the bank of a river during the Later Stone Age gathered material for their tools in the river-bed where, as likely as not, the stones they collected were derived from an implement-bearing deposit of the Middle or even the Earlier Stone Age. In this way, Stone Age man could, and indeed often did, transport a millenia- or million-year-old artifact up from one geological horizon to another often very appreciably higher and therefore later. I have frequently found Old Palæolithic bifaced tools, such as hand-axes, used as cores or fabricators on Upper Palæolithic " living floors "; and I have traced the " floor " of the hand-axes to a deep-buried aggradation in the vicinity. To the trained eye, this particular pitfall is made apparent by the different physical appearances of the old and the new, or by double patination on the transported and re-used pieces, but in some cases it is by no means easy to distinguish between them and so to avoid the trap—a trap which is particularly dangerous where we have a living-floor on a bed of clay that overlies another living-floor below the clay. In such a case, the imperviousness of the clay to surface water can cause the implements which occur on the clay to weather much more rapidly than those which lie below it. And if in the first instance the

deep-buried implements were covered before they had become appreciably weathered either by incrustation or by abrasion or rolling, we can, and actually do, find that the later, more superficial specimens are much more heavily weathered and altered and look very much older than do the more protected specimens which underlie them. In such a case, a recently derived piece transported from the lower to the upper deposit may actually appear more recent than its new bed-fellows.

And that which men did in the Stone Age they still do! There is in our midst the thoughtless field-worker who will take material he has gathered in the bed of a stream up on to the bank for examination and sorting prior to his final selection of pieces—and leave his discards on the bank; on an entirely different geological horizon from that on which they naturally occur. The practice is unfortunately not at all unusual, and in the name of posterity it cannot be sufficiently condemned. Pitfalls are plentiful enough in all conscience; it is not only thoughtless, but entirely purposeless, to add to their numbers. I must therefore remind my readers that as long ago as 1604 Friar Bacon said in his "Prophesie": "Now pitfalls are so made that small birdes cannot know them"—a truism in which we possibly also have the reason why "small birdes" continue to make them.

We also have the case of pebbles originally broken and chipped or flaked by glacial action during Carboniferous times occurring in the same deposits and literally side by side with pebbles artificially shaped by man during the earlier stages of the Quaternary Age. Many of these naturally shaped stones bear a striking resemblance to the artificially shaped Pre-Stellenbosch Pebble Culture tools, and in the absence of such evidence of glacial action as striations on the flaked surfaces of derived specimens, it is often extremely difficult to distinguish the natural from the artificial. This phenomenon is not uncommon in certain stretches of the Vaal, where material that is today recovered from the implement-bearing Older Gravels was derived from the glacial tillites. The Abbé Breuil was the first to detect and record the potential pitfall (1943), and he has more recently drawn attention to the fact that these glacially-shaped pebbles may be found in any of the river gravels that contain human artifacts (1944); indeed, they may be found in gravels or deposits that do not contain artifacts and may be mistaken for artifacts.

Another common and most dangerous pitfall is hidden in the fact that no interred bones can ever belong to the level or "floor" on which they occur. The detection of the mouth of a grave and therefore the time-horizon of the burial can be a most difficult matter—and if one is to avoid the pitfall and therefore avoid misinterpretation, one cannot be too careful in excavations which include burials. Such pitfalls are too well

known to need emphasis, so I propose in this essay to use illustrations which are purely picturesque; a few may even seem frivolous, but each contains warnings which no field-worker can afford to ignore. I have selected five, the first of which is

THE STORY OF AN AXE.

During a visit to a farmer near Knysna early in 1922 I noticed a well-ground and polished Neolithic axe on the desk in his office. A wood-cutter had brought it in from the forest. When sent for, the man said he had picked it up near the road to the bridge at the bottom of Phantom Pass. At that time only three Neolithic-type axes had been discovered in South Africa, and I was naturally most intrigued and interested to come across a fourth. Of the three recorded specimens, one was from Grahamstown and two from Knysna, all of material that can be matched locally. "These three relics," said Péringuey, "stand alone, and an explanation of their presence would be merely speculative" (1911). The next nearest specimens were from Central Africa: the Congo and Uganda. To find any evidence of the Neolithic Age in South Africa at that time was therefore rather exciting.

I lost no time in sending this new find to Péringuey, and on 25th February, 1922, he replied that in his opinion it was not of local manufacture. "It certainly not only resembles the European Neolithic," wrote Péringuey, "but to me has been accidentally dropped where found by a European. There are a certain number of Scandinavians at work at Knysna. The material is a mud-stone. This, however, is not of much help, because similar stone could be found here in the Karroo." Périnquey was partially influenced by the two previous Knysna finds, and obviously suspected that this new one was of European origin. When I submitted the specimen to Prof. S. J. Shand, the well-known petrologist at Stellenbosch, he said it was made of a mud-stone which could have been found just north of the Outeniquas. I therefore felt that the mystery of the three Knysna specimens had to be cleared up. In consequence, I approached Mr. Charles Thesen the head of the well-known timber firm and son of the Thesen who came to South Africa from Norway and settled at Knysna in 1869. He had shown a keen interest in my discoveries of Old Palæolithic settlements in the district, and I knew that he would be interested in this new find. Although he recognised its artificiality, he did not recognise the stone, but when I mentioned Péringuey's suspicions he immediately told me that a Norwegian whom he knew had come to the Cape, had collected and sold stone implements as a boy in Norway, and that he had brought a small series of Neolithic axes out with him. The Thesen family once had some of these but they had disappeared. "Possibly," he said, "they were given to John Rex"—the only other local

collector in the area at the time. "Oh, yes," said Rex, when I called on him, "I have two." Both his specimens were of flint and obviously of European origin. I then got into touch with Prof. Shand again, told him the full story, and asked him to re-examine the stone. After months of waiting, while I incidentally discovered another specimen of flint, the Norwegian origin of the axe was confirmed—and so we now know that the Neolithic axes of Knysna, some of which may possibly be widely scattered in and even beyond the district, were brought to South Africa from Norway in the latter half of the nineteenth century. No wonder Péringuey refrained from speculation! Since then true locally-made Neolithic-type axes have been found in South Africa, but cautious interpretation is still necessary. Had Mr. Thesen not recalled the exploits of a countryman, the problem may possibly have remained unsolved, especially as at least some of the axes are of material that occurs locally.

The second pitfall is from the Free State: it was encountered two years later, and is

THE STORY OF A BOTTLE.

This has nothing to do with prehistory, but it is an excellent demonstration of how meaningless depth can be in relation to age. While building a bridge over the Modder River at Glen, some miles north of Bloemfontein, I had occasion to sink a moderately deep excavation for the left abutment, the foundations of which were reached by sinking a caisson through over 30 feet of fine sand to bedrock. Removing sand from below the cutting edge of the caisson while I was fortunately present one afternoon, a Native worker exposed a mineral-water bottle at a depth of over 20 feet below the surface. The bottle was undoubtedly *in situ*, and as it contained a loose marble in its dimpled neck it could not have been much more than a quarter of a century old—possibly a relic of the Officers' Mess of the garrison stationed there at the time of the Anglo-Boer War. Had the bottle been a *biface*, one might have been impressed by the depth at which it was found—but a glass bottle was quite a different matter; and the depth at which it was found certainly called for an explanation.

The bridge crosses the river on a sweeping curve. Circumstances beyond the engineer's control dictated the selection of a site that would ordinarily not have been chosen. The excavation referred to was on the inner curve of the bend, and until the bridge and a weir immediately up-stream of it were built, the tendency of the stream was to erode the right bank or outer curve and to silt up the left or inner bank. Surface drainage increased the latter tendency. The result was that from the time the bottle was dropped on the left bank to the time the bridge was built, the water's edge had receded and the bank had been silted up to a depth of over 20 feet where the bottle lay.

Yet there was nothing else to show that such a great change had come about in so short a time.

This movement of a river may seem strange to those unfamiliar with the behaviour of South African streams, but it is not at all unusual in many areas. The most remarkable case within my experience occurred in the north-eastern Cape where, after a flood, a bridge was left high and dry with the stream it had previously crossed nearly a quarter of a mile away. The engineer's problem then was to decide whether to build a new bridge or to take the stream back to the old. We took the stream back, and, after nearly a quarter of a century, it fortunately is still there!

My third experience also has the building of a bridge as its background. It occurred in 1925, and is

The Story of a Wheel.

To support a tall bridge-pier in the centre of the Sand River on the farm Jakhalskraal, in the Winburg district of the Orange Free State, we had to sink a caisson through about 25 feet of a super-saturated deposit of sand in order to reach a sound foundation. The cutting edge of the caisson ultimately came to rest on a boulder-bed about 23 feet below the river-bed. While clearing the bottom prior to sealing the caisson, I was delighted with the appearance of a very rolled artifact—apparently of Old Palæolithic Age—but amazed, almost immediately after, to see fragments of an obsolete type of heavy wagon-wheel appear. The wheel was found on the boulder-bed nearly 23 feet below the river-bed. There could be no doubt that it was *in situ* at the time of its removal. How did it get there?

Enquiry revealed that when the earliest Europeans occupied the area towards the middle of last century, a ford was constructed about a quarter of a mile upstream of the bridge site. Presumably a wagon had foundered while crossing the river, and in the course of time the portion of the wheel we recovered was carried downstream and sank as it went. This could easily have happened in that the bed of the river is of sand, which becomes very disturbed and is readily transported during floods. The weight of the wheel prevented its superficial transport in the first instance and helped it to sink in the second.

The fourth potential pitfall is

The Story of a Bead.

In 1936 I recovered a necklace from a witch-doctor in Sekukuniland. The necklace included the vertebral column of a small snake and eleven glass beads. Ten of the beads were typical Nigerian spheroids of the opaque, white-spotted, black variety—each about 1 cm. in diameter—and the eleventh a somewhat larger but typical pale blue translucent Roman melon oblate—at least that was my impression at the time. When

the witch-doctor was asked where he had got the beads, he said the spotted blacks were given him by an old woman and the melon-type he had inherited from his father, who had been a witch-doctor before him but had since died. The old woman said she got the blacks from a son who had served in France in a Native Labour Corps during 1914-18 War, and that as far as she knew he had brought them out from Europe.

The presence of the Nigerian beads may be accounted for by transport from the basin of the Niger possibly as a trophy or souvenir by a member of the Foreign Legion to France and thence to South Africa by the Native, but the Roman bead presented a more difficult problem. And was it Roman? "Yes," said the museum authorities when I showed it to them in Cairo in 1937, "it is definitely Roman; a well-known variety"—and they showed me similar types from the North African coast.

Among the beads we have from Zimbabwe and related ruins and settlements in South Africa are several ancient Arab and other varieties mixed with mediaeval and later trade beads, fragments of Chinese porcelain of the Sung and Ming Dynasties, Persian faience and fragments of other articles of domestic use or trade value. The great mass of these trade and other goods is post-mediaeval, but among them we occasionally find survivors from a remoter past, and there can be little doubt that this Roman bead is one of them. Had it been lost by the witch-doctor and later recovered by one of the romantic interpreters of the Zimbabwe Culture, there is no knowing what interpretation might have been put on it.

Glass beads have to be most carefully interpreted. Early this century a German firm of bead-makers copied the well-known blue hexagonal or so-called "ambassador" beads that are found in the Zimbabwe Ruins of Rhodesia and the Transvaal. Because of the value attached by certain Natives to these beads, a German merchant imitated them, hoping to make a considerable profit from the sale of his imitations, but the Natives detected their modernity and would not buy them. The beads were then hawked round the country, but without success, until, in 1908, a market was found for them in the Transkei. Xosa maidens wished to buy them in order to adorn the tokens they gave their young men when they became betrothed. But they only wished to buy one at a time, and as the smallest coin in circulation was a penny, the beads were sold at an enormous profit at a penny a piece. For reasons known to women only, the vogue died out a few years later, and the bead was left off the emblem of engagement—with the result that those already sold were discarded and in time scattered no doubt in their thousands throughout the Transkeian territories. As a result of exposure to the elements, sand-blast; and so on, these beads will in time acquire a patina which may make it difficult to

distinguish them from the true Zimbabwe Culture types—and we may find a claim that the southern limit of the culture is to be sought in the Transkei!

I have an interesting story of a North American Indian arrow-head picked up on the veld by a schoolgirl on a remotely situated farm in the district of Steynsburg. It is tanged and of chalcedony, which cannot be distinguished from material which occurs locally—and no one living in the district at the time was able to recall a local collector or anyone at all interested. We all know of Brandon flints dropped on the veld and occasionally on Stone Age sites by the early pioneers who used muzzle-loading, flint-lock guns, but lest we forget that Nature can do what men did at Glozel, I feel I should extend this excursion into the picturesque by recording

THE STORY OF A BUDDHA.

Some years ago a Harrismith farmer dug a water-furrow. At a depth of about seven feet below the surface of what he took to be undisturbed, virgin soil, he found a small stone figure of a Chinese Buddha. He took this into town and showed it to the local Inspector of Schools, who happened to be a keen amateur collector. The Inspector sent it to me as having been found at depth *in situ* in undisturbed soil. These facts and the nature of the object, and possibly the presence of Chinese wares in the Zimbabwe Culture, impressed the Inspector sufficiently to seek an explanation. All I could do was to tell him that the stone was pagodite and the carving certainly Chinese, but at the same time I reminded him that the Voortrekkers had passed this way in 1837, and added that I suspected that the figure, which had once possibly adorned a tea-caddy brought from the East in the days of the Dutch East India Company, had been lost or discarded when broken in the area as the trek passed through; that in the course of time it had become naturally buried and overgrown, and that after over a hundred years it reappeared in a deposit which seemed to be much older than it actually was. By itself, depth is not necessarily an indication of age—as the soda-water bottle of Glen so clearly showed. Yet it is one of the commonest pits into which the amateur falls.

Another " virgin soil ' story is told by Schofield, where he cites the case of a Roman coin " found at a depth of two or three feet by natives who were digging a trench through virgin soil " in Southern Rhodesia. The coin had been struck in Alexandria about the year A.D. 270, and had Schofield not known " that at least two members of the Public Works Department staff carried pocket pieces of this very period during the construction of the building near which the coin was found," it is extremely probable that the mystery of its presence in Rhodesia would have remained unsolved and, incidentally, have given rise to considerable controversy. Schofield's contribution on dis-

coveries of ancient coins in South Africa should be read by all who are interested in pitfalls (1942). After recording the discovery of a number of Ptolemaic, Roman, Byzantine, Indian and other coins, Schofield sums up his views by saying that "none of the ancient coins have any real bearing on the archæological problems of South Africa, as they are all purely sporadic in their occurrence.'

In conclusion, I feel that as a builder of bridges, both actual and archæological, I may be permitted to close this contribution by altering the mediæval Leonine proverb which tells us that "he falls not from the bridge who walks with prudence" to:

"*Non in foveam cadit, qui cum sapientia vadit.*"

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ARCHAEOLOGY OF SALDANHA BAY

BY

P. BATEMAN.

Read 4th July, 1944.

South African Journal of Science, *Vol. XLI, pp. 353-360, February, 1945.*

SEA ANIMALS AMONGST THE PREHISTORIC ROCK PAINTINGS OF LADYBRAND

BY

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Hon. Professor, University of the Witwatersrand.

With 1·Text Figure.

(With Addendum on " Prehistoric Fishing Scenes " by Walter W. Battiss.)

Read 3rd July, 1944.

While I was recently copying the rather faded paintings in the "Rose Cottage Cave" in the Platberg on the townlands of Ladybrand, mentioned by Stow (1905) and which, except for one figure, Miss Helen Tongue had given up deciphering, I saw in the midst of a great many animal studies, including a number of lions, and human figures, some fairly big fish-shaped forms, several of which I think should be considered as marine animals.

One figure in the centre of the wall at the back of the cave, which was published by Professor van Riet Lowe in the *Cape Times* of December 4th, 1929, seems to me to be that of a whale, stranded on its back, with one of its forward fins standing upright. The extremely thick attachment of the tail and the forward part of the body, which is very swollen, is unlike a fish. A strange appendage, perhaps the tongue, is attached. The painting is 43 cms. long from the head to the middle of the tail, painted in reddish-brown, and superposed on other paintings of various techniques, older and far more faded, drawn in yellow, orange and light red lines and light reddish-yellow or orange figures outlined by a brownish-black line. I think that the small human figures painted below are probably far older and have nothing to do with the whale.

All the paintings of fish are near the entrance on the left wall as one goes into the cave. The best one is painted obliquely, at about the height of a man, has no paintings near it, and the silhouette is clear. The tail is definitely heterocercal and obviously that of a shark or at least of one of the same family of fish. The pectoral and anal fins are indicated by a single oblique line. The dorsal fin is omitted. As for the head, the very pointed snout can be seen, the receding slightly open mouth, and a big

eye with its pupil. It is painted in a brownish-red and measures 44 cms. in length, of which 11 make up the tail. It seems to me more recent than a group of eight small people painted near its tail. A little nearer the entrance are two different groups of fish, one of four, and the other of two. In each of these groups there is a fish with a heterocercal tail similar to the shark, but other details are neither typical nor well preserved. The most complete painting has a large head, and a length of 48 cms; the other's head is faded and only measures about 34 cms.

Mr. Paul Loewenstein gave the Archaeological Survey a slab which had been removed from another shelter in the neighbourhood of Ladybrand many years ago, on which is painted a school of sea fish being attacked by dolphins. This interpretation was given spontaneously by several sailors who happened to see the original in the museum of the Survey. Actually, the silhouette of all these creatures is uniform, a head with convex brow above the elongated snout, seems to agree with the shape of a dolphin, but the tail is invariably forked; there is one dorsal fin well to the back as in dolphins, two small pectoral fins and two anal ones, and one small fin between the latter and the caudal one, as in fish. The movement in the school of fish (there are 53, several having been mutilated by the removal of the slab) attacked by four dolphins (of which one has nearly disappeared), is extraordinarily well reproduced. Mr. Walter Battiss discovered in a painted rock shelter on the farm Uysberg near Ladybrand, a great many fish very like these in size, execution and red colouring. Several slabs have been cut out in the past and it is established that Lowenstein's slab came from this farm. In an addendum to this paper, Mr. Battiss shows the fine fishing and navigation scenes which he has copied. To paint them the artists must have known the ocean, or at least a lake of considerable size. Mr. Battiss has already made known to us a scene of similar type from another site, but with only one boat.

Ladybrand is 210 miles from the sea as the crow flies, and Basutoland with its high mountains lies athwart this route.

We have to admit that the painters of these figures must have seen marine animals and the coastal scenes which they painted in their rock shelters at Ladybrand. Therefore they must have gone to the sea. I read somewhere—unfortunately I cannot recall where—that certain Bushman tribes in the non-hunting season, I suppose the winter, went to camp on the coast to eat fish and shell-fish and then returned to their hunting grounds.

People who are adept at understanding modern Bushmen in historic times consider them as being so firmly attached to their hunting grounds that they never left them. But I think that a great number of the paintings, and especially those of the Rose Cottage Cave, are several thousands of years old, for they are obviously fossil. Perhaps this confinement to hunting

grounds did not exist, or not as strictly, in those very far-off times. Such is the problem set by the sharks and cetaceous animals of Ladybrand. When I showed the copies to Professor van der Horst, Head of the Department of Zoology at the University of the Witwatersrand, I was glad to find that he agreed with my interpretation and tender him my thanks for his help.

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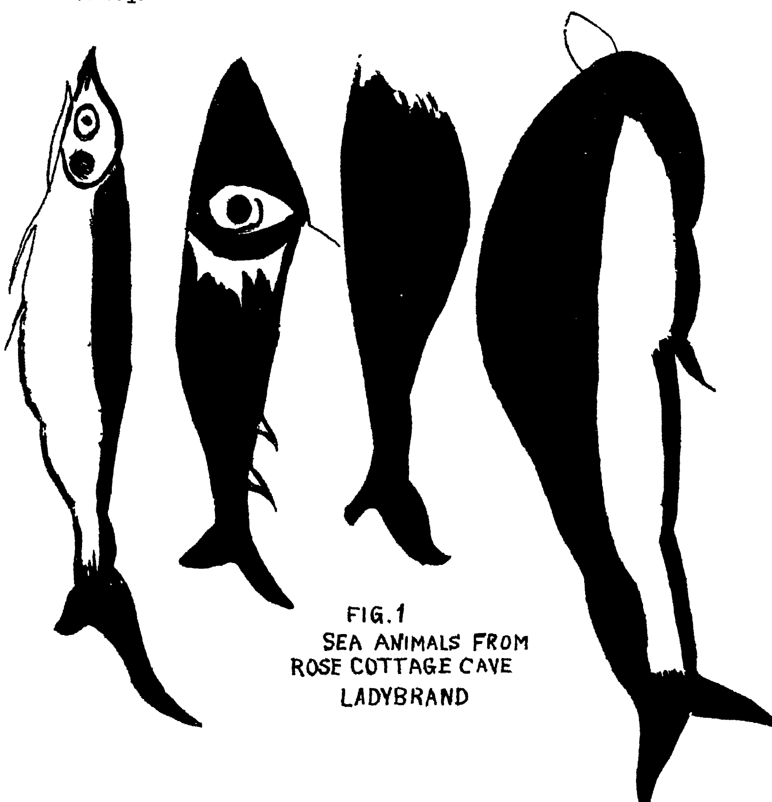


FIG. 1
SEA ANIMALS FROM
ROSE COTTAGE CAVE
LADYBRAND

ADDENDUM ON "PREHISTORIC FISHING SCENES,"

BY WALTER W. BATTISS.

With 2 Plates.

The representation of fish is not uncommon in prehistoric art. In Europe there are examples, such as the salmon carved in bas-relief at the Gorge D'Enfer, the trout engraved on the floor at Niaux, and the finely engraved fish at Pindal (Cantabria).

Stow's and Tongue's copies of South African prehistoric rock-paintings often show fish and I have seen clear representations of fish in many rock shelters. Some of the sites with paintings are at Himeville, Natal; "Ventershoek," Wepener district; "Uysberg" Ladybrand district, and "La Belle France," Rouxville district, in the Orange Free State.

But while representations of fish are common, it is unusual to find human figures associated with fish, so some of the rock paintings I recently copied are of the greatest interest because they represent men catching fish.

All prehistoric artists had a predilection for painting "hunting for food" scenes so we find their representations of men hunting the elephant and the eland, of women digging up edible roots and now we have these fishing scenes.

Mr. Alec. W. Foubister, of Himeville, Natal, took me to the site where I found the composition of men in boats harpooning fish. I was keen to see a site where horsemen were depicted and Mr. Foubister said he could show me such a site. If he remembered correctly he thought there was also a scene of men catching fish. My patience was sorely tried as I waited a week at the Himeville Hotel for the rain to stop. Then Mr. Foubister took me to the rock-shelter near the summit of a mountain gateway known as "Mpongweni Mountain" in the Drakensberg, towering above the Polela River and about fifteen miles from Himeville.

Here there are excellent paintings of horses and horsemen but the choicest painting was a fishing scene.

It is a beautiful and rare composition in faded black silhouette occupying the face of a projecting sandstone surface. It is isolated and has no superpositions. I interpret this scene as nine nude men in boats harpooning fish while a tenth man is running below a boat to impale a large fish (Fig. 2). One of the men in the boats appears to be directing operations, for he has one arm raised. The fish are painted with understanding, for large and small ones are depicted and possibly a fisherman could identify the varieties.

As a composition, with the boats encircling the shoal, it is at once attractive and in its simplified pattern and brush treatment is reminiscent of Japanese art.

Although the scene is obvious in its content, a certain mystery attaches to this painting. What race of men are in the boats, where did the painter witness the scene, and when was it painted?

To begin with, I do not believe the painting is a figment of the artist's brain, but consider it in the same light as the well-known battle scenes, cattle raids and hunting episodes so frequently represented in the rock-shelters. In other words, I consider this fishing scene as a scene actually witnessed by the artist.

Yet its locality is so unusual. A fishing scene—men in boats harpooning fish in a large expanse of water—in a rock-shelter far up in the Drakensberg; surely that is unusual! So far no other boats have been seen in our prehistoric rock paintings. The first impression I gained was that the artist was here representing a coastal fishing scene he had witnessed on his travels.

Now only a few weeks ago I was delighted to find another harpooning scene, this time in a rock-shelter in the Uysberg, Ladybrand district. This scene is also in monochrome, but is not in black silhouette, but in "Claret" red silhouette. A man is shown thrusting his harpoon into a fish while another man stands expectantly behind him to catch a fish thrown from the harpoon. Behind these figures a quiver lies on the ground. Below this quiver is another quiver and a small buck running away (Fig. 3). There is in the lower left corner a crude figure in faded white which appears extraneous to the fishing scene.

I do not believe, from the appearance of things, that the men harpooning the fish were added lated by another artist; so the harpooners and the fish complete a single composition.

In the same rock-shelter are paintings of fish in black, in white, in red monochrome. One or two, however, are simple bichromes.

Shortly afterwards I found a small scene with a man and a fish in a rock-shelter on the farm "La Belle France" in the Rouxville district. The man actually has a fishing rod! This scene is in faded red. I showed this painting to the Magistrate of Rouxville, Mr. Colin Elliott, who accompanied me to the site

These last two fishing scenes incline me to the belief that they represent fishermen catching fish in the rivers near their rock-shelters and they incline me to alter my first impression of the Mpongweni harpooning scene which I once believed to represent a fishing scene at sea. It seems possible that it can

represent a fishing scene on a stretch of inland water, perhaps some small lake or dam in the mountains, perhaps on a river beach, as on the Polela River below Mpongweni.

It is difficult to determine the chronological position of these fishing scenes since obvious superpositions are lacking, but there is no doubt that they belong to an anecdotal period, the style is in each case one of ease and freedom, and planned composition holds the different parts of each scene together.

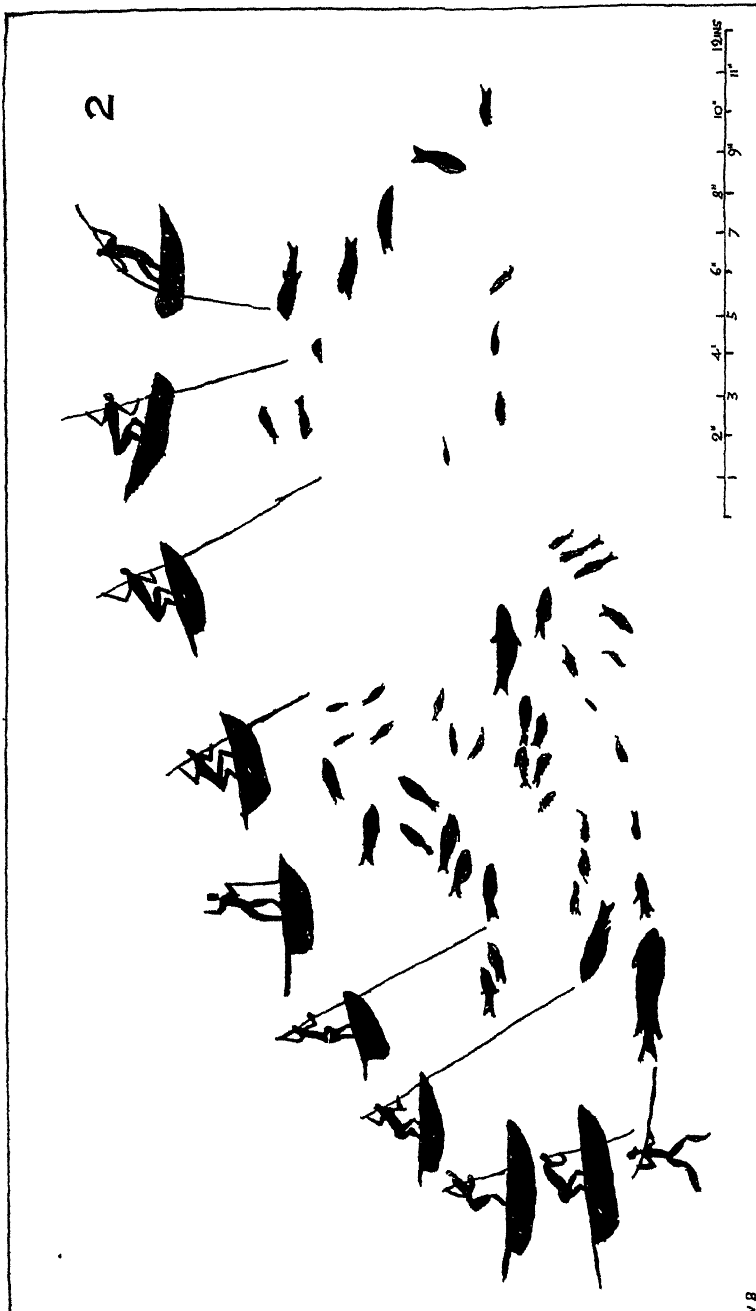
The artists who painted these fishing scenes had a "romantic" approach to the life about them, and as such their art is warm and lively as opposed to the "classical" approach which is cold and restrained.

My thanks are due to Professor C. van Riet Lowe, Director of the Archaeological Survey, whose perspicacious eye was quick to seize on the significance of these paintings in prehistoric art. Without his interest it is possible that these fishing scenes might have been dismissed as merely interesting, whereas he stresses the point, which I believe, that these scenes are rare prehistoric paintings pregnant with new speculation and theory.

INDEX TO PLATES.

Fig. 2: A rare fishing scene from a site in the Drakensberg. This scene, which represents men in boats harpooning fish, is painted in black silhouette in a rock-shelter near the summit of the Mpongweni Mountain, in the Drakensberg, and about fifteen miles from the hamlet of Himeville, Natal.

Fig. 3: A prehistoric rock painting from a rock-shelter in the "Uysberg" Mountain, near Ladybrand, Orange Free State. Note the man harpooning fish. The whole scene is painted in monochrome, in a "claret" red colour. In the lower left corner is a figure in faded white which remains unrelated to the fishing scene.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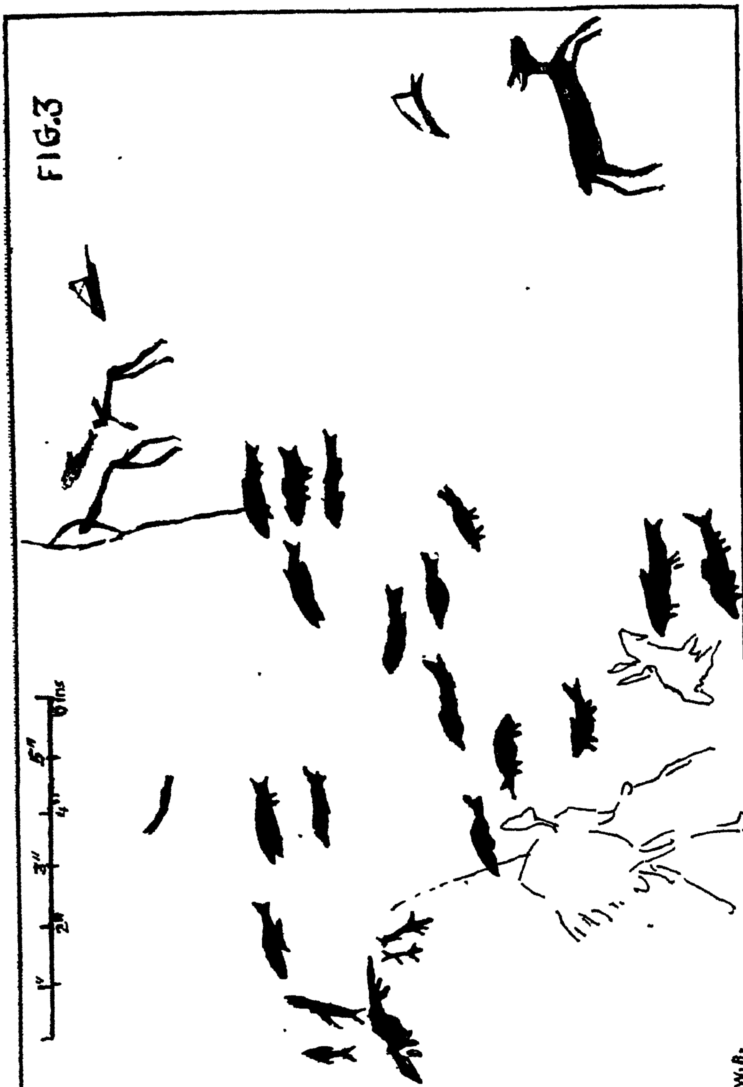
FIG.3
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2"
3"
4"
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South African Journal of Science, *Vol. XLI, pp. 361-374,*
February, 1945.

THE OLD PALAEOLITHIC AGE IN RELATION TO QUATERNARY SEA-LEVELS ALONG THE SOUTHERN COAST OF AFRICA

BY

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Hon. Professor, University of the Witwatersrand.
with Addendum by G. Mortelmans.

With 6 Text Figures.

Read 3rd July, 1944.

The Southern Coast: General.

Sea-levels recognised by South African geologists and ancient beaches of South Africa, when one consults the very fine books on this subject (Krige, 1927; Haughton, 1938; Du Toit, 1939), are graded from 3,000 feet down through 2,600, 1,300, 1,200, 1,000, 900, 800, 700, 400, 330 to 200, 120, 95, 70 and 45 feet O.D. They also established the existence of old continental levels under the present sea at 45, 122, 140, and 157 feet; but, while these submarine levels are attributed to the Quaternary (Glacial) Age, very few of the beaches, raised above the present sea-level, have been classed as of that Age. Only the lowest near Cape St. Blaize at Mossel Bay (Goodwin and Malan, 1935), containing Middle Stone Age (?) remains and overlaid by a big station of this industry has been described as Quaternary. As for the higher levels, most of them are assumed to belong to different stages of Secondary, Cretaceous and Tertiary times. Obviously, we have this sequence: the 400-800 feet levels of the platform between Port Elizabeth and Knysna, dating from the dawn of the Tertiary; then the Lower Miocene 330 feet level of East London, and finally the Mio-Pliocene levels of about 1,200 feet between Riversdale and Bredasdorp, all due to falling or rising of the sea-level. There is then a gap in our knowledge of sea-levels until the end of the Quaternary. If a fall to levels lower than the present ones is accepted, and this drop was due to frozen water derived from the oceans (which is the usual explanation, though it may not be the only one), then, according to the usual theory about glaciations, this must have occurred four times, with important rises between—rises far higher than 45 feet, an altitude which only corresponds to the rise in sea-level due to the last European interglacial epoch. We should therefore find sea-levels, connected with the various stages of the Old Palaeolithic, at higher levels than 45 feet.

We know that, in Morocco and Portugal, marine beaches associated with Old Palaeolithic industries are found at descending heights of 90, 60 and 30, 20 and 10 metres (Neuville and Ruhlmann, 1941; Breuil and Zbyszewski, 1942). I would have liked, after having seen the facts stated about the Portuguese and Moroccan coasts, to see whether or not similar conditions existed in South Africa. Unfortunately, the present war atmosphere is not very favourable for such an enquiry. I could not, for instance, obtain contoured maps required for such a study, nor could I make all the excursions and exploration needed along the coast. There were also other obstacles.

In spite of this, however, I shall try to marshal the facts which are known to me, either personally or through intermediaries, and which are capable of being applied to such an hypothesis.

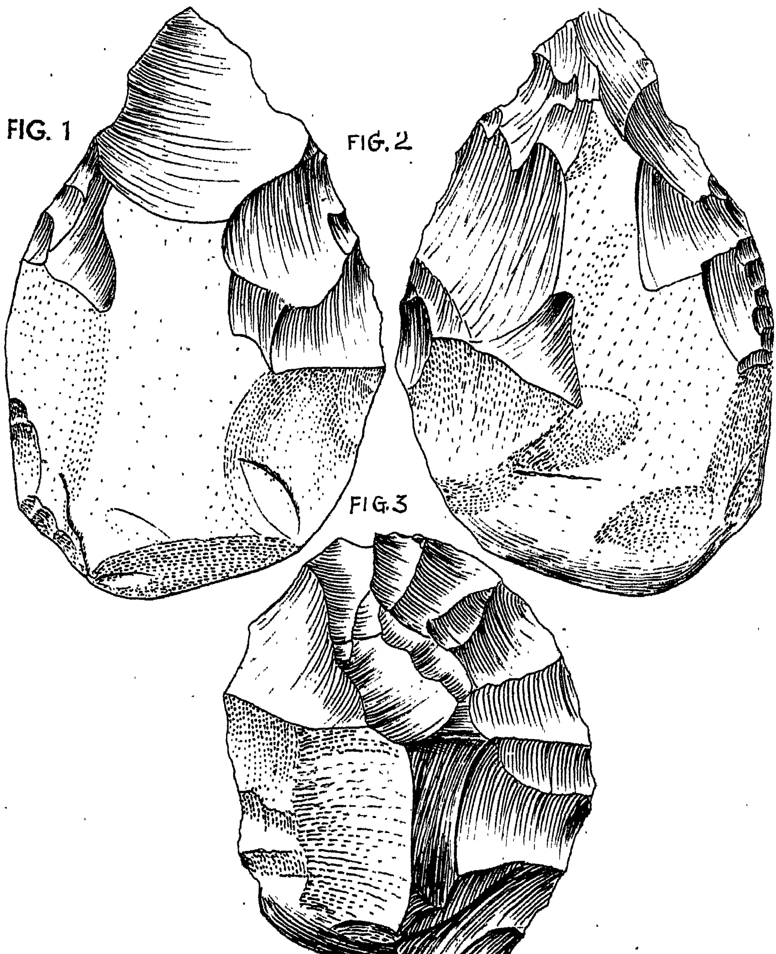
1. *Mossel Bay.*—Guided by Mr. A. J. H. Goodwin, I visited the sites at Mossel Bay on 23rd September, 1929. I saw the raised beach known as the 45 foot level, and with him, I think, I picked up a few chipped tools contained in the gravel, which, as is known, is beneath the big Middle Stone Age Station (Goodwin and Van Riet Lowe, 1928). It is not certain if the few poor specimens from this raised beach belong to an older phase of the Middle Stone Age or to a late phase of the Fauresmith. The examination of this section of the beach will have to be repeated several times if we are to be more precise. Indeed, at appproximately the same low level, several appreciably evolved hand-axes in greyish-blue quartzite have been found in the low-lying gap, an old strait, between Fish Hoek and Noord Hoek, and a similar industry, not rolled, lies on the lower terrace of the Eerste River at Spier Farm near Stellenbosch. This shows that, starting from the latest date for hand-axes on the southern coast, the sea has not risen higher than the 45 foot contour If the industry is not Fauresmith, it is very near it.

Mr. Goodwin took Mr. and Mrs. Harpur Kelley and myself to the big evolved Stellenbosch station in the pinewood on the golf course above Mossel Bay. The unworn industry found there in the yellow sand, which is reddened where it is exposed, is made from the pebbles on an underlying beach, covered over by the sand at an altitude of 550 feet.

Amongst many specimens picked up at the same site by Mr. J. H. Power and given by him to the McGregor Museum at Kimberley, I noted several with double patina; originally picked up on a beach where waves had worn them after they had first been shaped by man, they had been collected a second time and retrimmed during a later period. One is a very pretty almond-, almost lance-shaped hand-axe, the narrowing point being the only portion of the tool shaped by man during the second period of occupation of the area. The old roughly trimmed surfaces are extremely worn, but enable us to see that when first shaped it

was a Middle Stellenbosch wide flake with a rather lateral bulb at the base. The less worn or fresher flake scars show that it was retrimmed during later Stellenbosch times. Its length is 16 cms.; its width 10 cms. (Text Figs. 1 and 2).

Another imperfectly trimmed short oval hand-axe was made under the same conditions, starting from a massive flake with bulb at the base, retrimmed a first time, then greatly worn. Its length is 11·8 cms. and width 9·5 cms. (Text Fig. 3).



Figs. 1, 2 and 3.—Old Golf Course, Mossel Bay.

Slightly below the road leading to the golf course site, is a reservoir near which, in 1929, big massive pebbles were being extracted from an outcrop of an ancient beach. I picked up

several trimmed and worn pebbles *in situ* at an altitude of approximately 450 feet above sea-level. I put them in the South African Museum where fifteen years later I found them still marked in my handwriting. Here is their description: two flakes trimmed from pebbles and roughly retrimmed along the edges by rather short faceting; they are very worn. A third specimen which looks more recent and is not much worn, is an ovoid pointed flake rather thin, with a lateral bulb on the base and wide curved point trimmed on the upper face. There are some signs of later re-utilisation of the point: length 10·3 cms., width 3·2 cms. I conclude from this that, at a relatively advanced stage of the Stellenbosch Culture, the sea at Mossel Bay still reached a level which we thought to be about 200 feet. I cannot ignore

FIG. 4

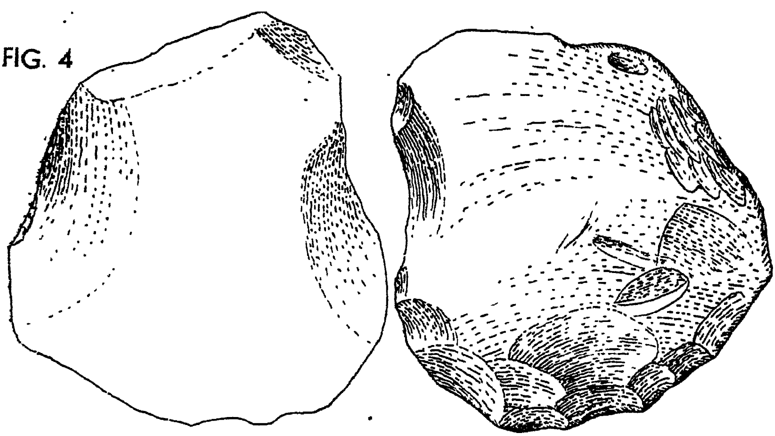
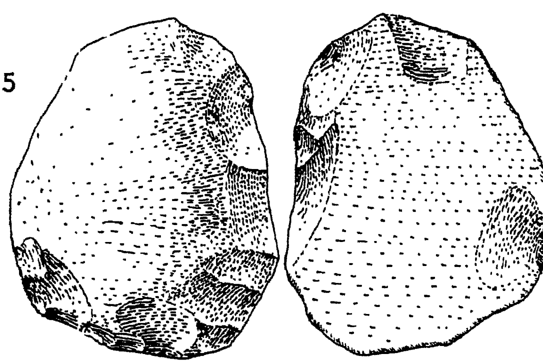


FIG. 5



Figs. 4 and 5.—Trimmed flakes from an old beach of about 200 foot at Mossel Bay.

the fact that at Knysna as at Still Bay, which we visited on the 21st and 25th September, 1929, we only found Stellenbosch tools of middle or evolved-middle type, right on top of the high escarpments, at the foot of which the sea now beats. On the slopes of

this escarpment, at a lower level, Middle and Later Stone Age tools abound as well as many "kitchen-middens some of which may belong to the Middle Stone Age.

When I returned to this hospitable land nearly two years ago, I had the luck to meet and appreciate the young Belgian geologist, Mortelmans, who was on his way to Knysna and at once I told him how worried I was by the problem of sea-levels in Old Palaeolithic times. I was therefore delighted when he returned to me with the news that he had absolute proof of the existence of a level in a Quaternary sea beach at 400 feet, cutting into a Cretaceous beach, but below a Pliocene plateau of marine gravels at 550 feet, and with a collection of well-worn specimens of very old Stellenbosch or Abbevillian-type tools from the area he surveyed at Plettenberg Bay, almost immediately above the hotel at the Keurbooms River mouth. He found more old Stellenbosch tools, still more worn and lower down, as well as Middle Stellenbosch also worn, in a 15ft. beach as described in this Journal (Mortelmans, 1944).

We therefore draw nearer to what the north Atlantic taught us in Morocco and Portugal.

2. *East London*.—Still further to the east, Mr. D. R. MacFarlane made an important collection of specimens from the heights near East London, at altitudes which he gave me as 350 feet at Amalinda and 250 feet at Brown's brick-field. Here he collected an abundant pebble culture industry which I was able to examine and accept. He did not find Stellenbosch tools lower than 120-150 feet and the rather archaic Middle Stone Age tools occur below even under the present-day beach. More to the west, Mr. F. Malan, of Wellington, collected partly in his excavations in a black earth lying on a 40-80ft. raised beach near Cape Hangklip, a huge series of very late evolved Stellenbosch of the same shape and bluish appearance as the tools already mentioned from the Fish Hoek-Noord Hoek gap, where there is also black earth. In 1929 I found a good many less evolved Stellenbosch tools on a ferricrete surface fairly high on the hill tops on both sides of the same gap.

3. *The Cape Peninsula*.—Mr. Goodwin and Dr. Petronella van Heerden also took us to Cape Point, where we collected under several dunes a large quantity of very fine and large Middle Stellenbosch tools of two dates: one lying in a basal laterite level and the other in a later grey, hardened dune superposed on a marine platform at an altitude of between 200-300 feet, below which, to the north, the remains of a Middle Stone Age beach is seen far lower down.

I did not find anything very definite in the eastern 70ft. beach marked on the map along the road to the south of Simonstown, but, thanks to a permit from Lt.-Col. J. C. Moolman who accompanied me, I was able to examine a place near the town where military barracks, etc., had just been built and where there are also several quarries above the road. After having

taken my barometric zero on the edge of the sea, I discovered above the road a beach with big boulders at about 140ft. level, rising steeply towards a small cliff which makes a sharp break in the slope at about 300 feet up. Towards the top, the covering of yellow sand reddens and more or less disappears, and the very oxidised gravels come to the surface. In various places I picked up heavy worn tools of very old Stellenbosch I, and others of Stellenbosch II, unworn or only slightly worn, all very iron-stained. The highest up, very worn, were found at an altitude of 280 feet. In the superposed sands of the 104-300ft. beach, very typical unreddened and unworn Middle Stellenbosch III tools are found here and there, coming perhaps from eluvial gravels which are covered by light-coloured blown sand. It is far more recent than the beach.

Above the cliff which stands at about 300 feet, and after a shelf, there is another beach also on a slope growing more and more steep, starting at a height of 320 feet and barred by a second line of cliffs about 600 feet up. Although I had not much time to search this second 300-600ft. beach, where the stones were extremely iron-stained, I found nothing in the coarse boulder gravel, but picked up in the superposed finer gravels two small trimmed stones, black with iron-stain and worn, which may belong to a pebble culture, but are neither Stellenbosch nor Middle Stone Age.

Mr. MacFarlane was good enough to take me to two other beaches not far north of Fish Hoek, lying one above the other at Pollsmoor in a wide sweep bordering a semi-circular bay. In the lower beach, which starts at the 45ft. level, he had found fairly big, very worn, chipped pebbles in the beach gravels, which were certainly re-deposited. He also collected implements which are at least Middle Stellenbosch, but unworn. According to Macfarlane, the base of the lower beach is at about 200 feet, and the top of the higher beach over 400 feet. The mountain which backs these two beaches has a big, clearly visible fault, and it may be that the difference in altitude between these beaches, when compared with those at Simonstown, is due to tectonic movement.

It is certain that, all along the South African coast, more than one similar occurrence of tectonic origin may have altered the altitudes of the beaches and industries, as Mr. G. Zbyszewski and I were able to prove in Portugal.

On examination of the eastern flanks of Table Mountain, one cannot but be struck by the low rounded hills which, at almost the same level of approximately 700 feet, surround the foot of its steep escarpments. Here very reddened gravels can be seen and, in 1929, I picked up Stellenbosch tools in that level at Constantia. In a recent letter to me Mr. Goodwin says that " there seems to be a marked ledge between 300 and 400 feet on which Stellenbosch (late) implements occur consistently —perhaps 320 feet." Mr. Goodwin also told me that he had

picked up many archaic types at other places on this line of hills. The gravels are spread out like a beach and are not confined to the beds of ravines going down the slopes where the gravels which are far less rounded have not at all the same appearance.

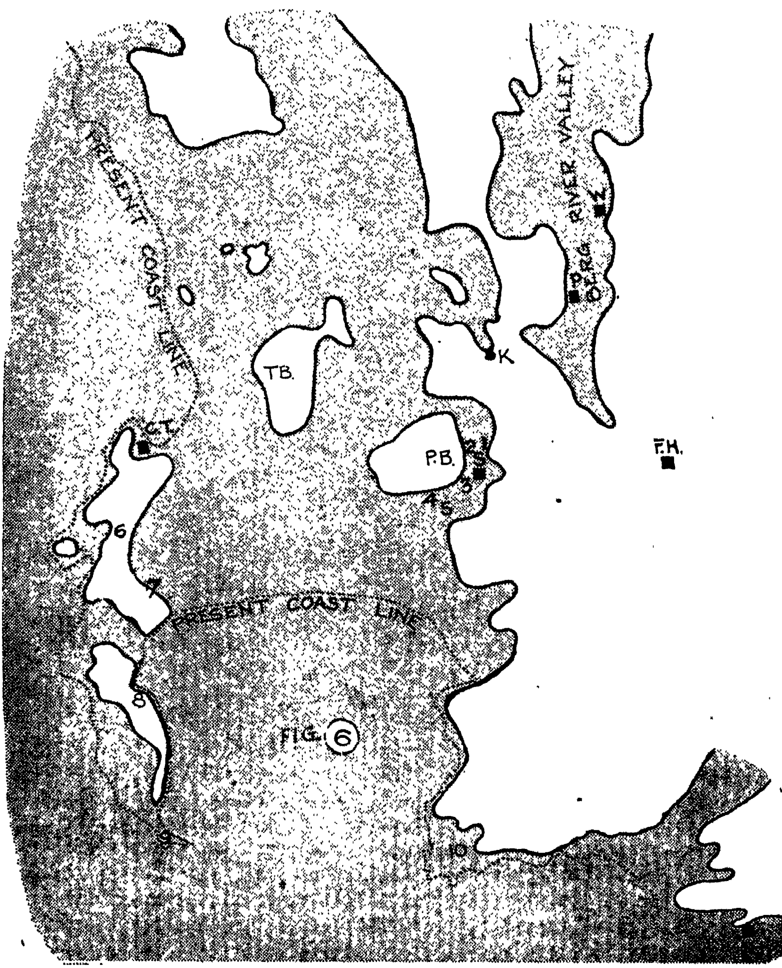


Fig. 6.—Map of Cape Peninsula and surrounding country showing the possible appearance of the area during the Earlier Stone Age of Old Palaeolithic Times when the level of the sea was about 400 feet higher than it is to-day.

CT: Cape Town; TB: Tygerberg; PB: Pappegaaisberg; S: Stellenbosch; K: Klapmuts; P: Paarl; W: Wellington; FH: Fransch Hoek; H: Hermanus.

1: Smit's Brickfield; 2: Blake's Brickfield; 3: Bosman's Crossing over the Planckenberg near its junction with the Eerste River; 4: The Olives; 5: Spier Farm; 6: Constantia Nek; 7: Pollsmoor; 8: Simonstown; 9: Cape of Good Hope; 10: Hangklip.

I am not aware that any Stellenbosch tools have ever been found lower down. We must remember that several times Table Mountain and the Cape Peninsula have been islands separated from the mainland when the Cape Flats were submerged by the sea and, when the sea sank, they were joined again to the mainland. If one admits that the low sea-levels coincided with the glacial and pluvial phases, and the high levels with the interglacial and interpluvial phases, it must have been during the former only that man of the various stages of the Old Palaeolithic Age could have had access to sites so detached from the mainland. The beaches must therefore contain worn stone tools dating from the earlier glacio-pluvial epoch, unless the human groups allowed themselves to become isolated or they already possessed a primitive means of navigation.

4. *Stellenbosch and the Eerste River Valley.*—We will now consider the implications of this theory applied, as is meet, to the other side of the Cape Flats, and first in the Eerste River Valley at Stellenbosch.

The present Eerste River Valley seems to be very young. There are two strong barriers of granite of border facies, one near the cemetery and the other at Spier Farm at Lynedoch station, and the passage of the river through them is difficult, especially at Spier Farm. In four miles, the Eerste River falls 90 feet—from 350 feet at Stellenbosch to 260 feet at Spier Farm.

In the section downstream of the town, the very coarse gravels in the river bed contain extremely worn and derived tools of Stellenbosch I-III types. These gravels, which are only slightly displaced by the present stream, are Quaternary. Unworn Stellenbosch IV-V tools occur in abundance on these gravels at Spier Farm. Therefore, except for superficial changes caused by floods, wind-blown sand and vegetable earth, nothing appreciable has happened here since the time the river deposited these gravels. But at a level always higher than 220 feet O.D. from The Olives at Lynedoch station, where Dr. Eric Nobbs has carefully collected material from extensive sites discovered on his land, a great quantity of Stellenbosch III and IV tools can be gathered. It is as if Man settled on the shores of a marine estuary at an altitude of about 200 feet. On the left bank, a wide flat stretch can be seen from The Olives, levelled at about the height of 400 feet and covered by a wide sheet of gravels, probably of marine origin, under a shallow layer of blown sand. This plateau, bounded on the east by the Helderberg Mountain and stretching southwards towards Faure and Somerset West, forms one of the most remarkable features of the landscape. Towards the sea, it ends in a very steep slope. Middle Stellenbosch, later than the gravels and made of pebbles collected in them, is plentiful here. In this region there is no trace of any other terrace, fluvial or otherwise. But, approaching the town, both road and plain rise all the time, and after having

crossed the Veldwachters Spruit, reach the site where a box factory is being erected on the left of the road near Stellenbosch, facing old gravel pits on the right and separated from them only by the road. On the side on which the factory is being built, there is a rather shallow grey gravel mixed with fairly recent humus, probably washed down from the foot of a lateral valley which has a gradual slope; this contains a late Stellenbosch industry and rests on an almost horizontal and smooth surface of granite which just appears at the surface here and there. It is not the river, I think, that has fashioned this shelf, but more probably waves. It lies between 300-320 feet O.D. At the same altitude on the right of the road is the old quarry with a ferruginous conglomerate of boulders and pebbles filling the cracks in the underlying granite and containing worn and iron-stained tools of Stellenbosch I type in the top of its mass. Unworn Middle Stellenbosch tools with a light patina lie at the base of the rather shallow superposed sands.

It is possibly from such a site that the makers of the Stellenbosch III and IV tools that characterise The Olives assemblages, gathered and retrimmed the old rolled Stellenbosch I and II tools—unless an extension of the same gravel existed at The Olives, where it may possibly still be found under the earth at the same height as that which appears at the surface at the box-factory site, viz. 300-320ft. O.D.

A mile nearer Stellenbosch, the road crosses the Plankenberg River near the cemetery at the classic "Bosman's Crossing" site discovered by Péringuey (1911). This is immediately upstream of another granite barrier which is also covered by coarse and very decomposed gravels of rather soft rock. Most of Péringuey's pieces were found on the gravel which is quite near the Stellenbosch station at 364 feet O.D.

On the opposite slope, another road rises westwards cutting through a deposit of analogous material, after crossing the Blaauwklip River. Dr. A. L. du Toit and I found *in situ* on the lower gravels (for they repeat themselves going down the slope), several specimens of unworn Middle Stellenbosch tools.

At the town itself and in the wide basin in which it lies, we are in the area in which Prof. S. J. Shand indicated three fluviatile terraces of 45, 18 and 12 feet (1917). The very low level of these shallow terraces is notable, corresponding to the very last or last few low-level sea beaches along the coast. It is not strange that worn Stellenbosch tools are found in them, since all the slopes and hill tops around are covered with them. The aggradation of these gravels seems to coincide with the very low beaches of 45 feet and less, as Prof. Shand has suggested. These deposits cannot therefore solve our problems, since they are too recent. In October, 1929, I visited the golf course, on the 400ft. level O.D. at just the spot Prof. Shand indicated; he classes it as partly on the oldest and partly on the middle terrace.

The Upper Stellenbosch industry there is worn by the river, although far less so than the older industries which are much scarcer on the same site. But near the highest hilltop at Lorraine (altitude about 500 feet) and at a place on the road near Helshoogte (more or less 600 feet) there are levels with pebbles, which are, I think, marine, but of various Tertiary times. The chipped tools are unworn. Just at the head of the pass there is a beautiful fruit farm at Helshoogte which we visited with Professors du Toit and Taljaard of the Stellenbosch University. We saw plenty of large boulders and gravel beds, probably also marine, the pebbles in which had served for the making of magnificent Stellenbosch II and III tools. According to Prof Taljaard the beach level was probably Oligocene at about 800 feet O.D., for another beach considerably higher which I did not visit, belonged to the Cretaceous Period.

The road from Stellenbosch to Paarl via Klapmuts rises up a gently sloping valley in which there are several brick-fields. At Blake's brick-field on the right bank of the Plankenberg River the deposits are very thick and there, on the clay, Mr Blake told us he found a mass of Stellenbosch tools in a very localised area—"as if there had been a hut." Except for three or four tools of Middle Stellenbosch type which we saw, the remainder had unfortunately been dispersed.

Smit's brick-field, which is opposite Blake's and is still being worked, yielded to Mr. H. S. Jager, who discovered its prehistoric deposits and took us there, a big and magnificent series of Middle Stellenbosch tools. These two brick-fields are at 350 feet O.D. In the latter, a large excavation has been made at right angles to the stream, in the gently sloping ground that constitutes the foothills of the Simonsberg. The excavations have revealed a deposit of gravel and coarse sand forming part of a terrace cut in Malmesbury Shales during Quaternary times. On these shales there is first a thick layer of bluish-grey clay, the colour indicating that it was deposited under water. This contained nothing. Then come beds of coarse quartzitic sand, mixed with gravel, pebbles and some boulders, with occasional signs of definite stratification. Some of the worked stones came from this rather shallow level and are more or less worn. But the greater number, including the specimens with double patina, were lying on the surface of the gravel, at the base of a yellow sand which is reddened towards the top and covered with vegetable earth. The altitude above the present sea-level is the same as the higher station at The Olives and the marine plateau of Helderberg Flats viz. 350 feet.

I am led to believe that this clay was deposited along the edge of a tidal lagoon connected to an estuary or *ria*. When the level of the sea began to fall, this clay was covered by a coarser beach deposit, a beach frequented by men who made tools of Middle Stellenbosch type. The trickle of water of the

Plankenberg drains a low granite plateau entirely denuded of quartzitic pebbles, but rich in white clay and fine quartz grains now cut through by the railway: it could not have produced the quartzitic pebbles which occur in the Smit's brick-field deposit.

5. *Paarl, Wellington and the Berg River Valley.*—Leaving Stellenbosch, very reddened gravels are not seen again until we reach Klapmuts, 550 feet O.D., where Mr. F. Malan collected excellent Middle Stellenbosch tools. Paarl, at 400-490 feet O.D., lies in the bottom of the deep valley which drops from about 800 feet near Helshoogte at Stellenbosch and is actually in the Atlantic basin through which the Great Berg River flows from Fransch Hoek to the sea. (Fig. 6).

In 1929, with Mr. and Mrs. Harper Kelley, I made an important collection from the slopes on the left bank of the Berg River near Paarl. During my recent visit, I did not have time to go over these slopes again. The tools I collected in 1929 were from slopes well above the valley. It seemed to me that the worn, more archaic specimens were at a higher level than those of Middle Stellenbosch types found a little lower down. Searching the gravels of the river bed, we only found a few flakes of far later date—possibly Middle Stone Age.

This year, thanks to the hospitality of Mr. F. Malan, of "Groenvlei," near Wellington, we were able to examine his very large collection and visit various sites, in spite of the great heat of March. I had already tried to classify the numerous and beautiful tools presented by him to the Archaeological Survey at Johannesburg (1939). This yielded excellent results. It showed that the complete sequence in the different Stellenbosch levels exist also at Wellington, and, if the discovery by Captain J. C. Smuts of a Pebble Culture* be included, it is almost certain that this preceded the long Clacto-Abbevillian and Acheulean evolution.

I hope to be able to speak at a later date of these most important occurrences, but only after a thorough study of all the material Mr. F. Malan has collected and briefly described (1939). Allow me just to say that the oldest rather worn Stellenbosch tools in his collection are greyish-yellow in colour, due to contact with grey clay derived from the decomposition of surface granite; that the old Middle Stellenbosch, rather weathered, has a fairly light patina, due to its lying on granitic sands which have softened the arrisses. The patina is present in the evolved Middle Stellenbosch, but one face is reddened and the arrisses are sharper. Later Stellenbosch tools have yet sharper arrisses, the rock is less decomposed and the specimens

* There is no doubt that these stones are worked, but I could not find them, as he did, *in situ*, which is not surprising since the quarry was being filled up. Mr. Malan showed me two other sites containing some of them, apparently lower than Stellenbosch.

generally whitish in colour with frequent signs of aeolian wear. As for the Upper Stellenbosch, it is often a dirty grey due to contact with humic soil.

The water-worn specimens which are not very numerous and often with later secondary trimming, seem to have been imported to the sites where they are found and mixed with the unworn ones. This transport and re-use of older pieces as well as my observations on patina apply to both the Paarl and Stellenbosch areas, including the high-level deposits at Stellenbosch.

The sites are graded along a series of rounded granitic hills at different stages of declining altitudes dominating from a height the foot of the valley, the neighbouring railway station at Wellington being at 324 feet O.D. The highest site I visited was at the reservoir, where Capt. J. C. Smuts found a pebble culture *in situ* at a deeper level than the very abundant evolved Stellenbosch. This site is at 600 O.D.; indeed. there are some sites higher, at 800 feet O.D., corresponding to the marine pebbles supposed to be Oligocene at Helshoogte at Stellenbosch. Other sites lower down are fairly regularly aligned. These were graded by erosion and are the remains of an extensive series of shelves going gradually lower and stretching as far as the eye can see. These shelves were first cut in the mass of decomposed granite by the action of the sea. There is a fine physiographic picture of what I wish to describe in Fig. 183, page 157, of the fine book by Dr. L. C. King on "South African Scenery: A Text-Book of Geomorphology" (1942). It shows the beginning of the dissection of a plain abandoned by the sea, caused by the streams running down from high land. It shows exactly what happened at Wellington three or four times, according to the successive retreats of the ocean. On the following page of the same book, Fig. 184, the extension of the coastal plains of South Africa and Moçambique in Cretaceous and Tertiary times are shown. In a lesser manner, this illustration probably also applies to events in Old Quaternary times in the area we are considering.

In no part of this area is there a great accumulation of pebbles. I imagine that these were brought down from the Table Mountain Quartzites, which cap the heights in the area, by the torrents of each epoch, and scattered by the sea along its shore, as on the granitic hills down-stream of Stellenbosch. The erosion of each granitic platform and its subsequent dissection in a series of rounded hills began at the time of their emergence and increased during later periods.

Many of the rounded hills were shaped before the appearance of Man, who, when he came, did not hesitate to use the quartzitic material he found there, but it is likely that tools shaped by him and subsequently worn by the sea, when it stood at 400 feet higher than it does to-day, should be found in this area. They are also found at greater heights, but there less

frequently, and they are often re-trimmed. They do not come from the present river, nor from the smooth slopes of later gravels which are immediately above the river—at more or less 12 to 45 feet—which on account of its low altitude, seems to correspond to all, or part of the three fluviatile Stellenbosch terraces described by Shand. I only paid a short visit to this gentle slope; it consists of a not very compact gravel, not iron-stained, containing a good many chipped stones, unoxidised and not much worn, except for those derived from a higher and older formation. Several seemed to me to be final Stellenbosch, almost unworn and unreddened. I did not see the remains of an older terrace higher up, but only the series of granitic rounded hills to which I have referred and which I attribute to the action of the sea It is there that Old Quaternary Man lived, when, on one of the lower beaches, the sea still beat against the foot of the mountain escarpments, perhaps at a height of 400-500 feet. Later the people of Middle Stellenbosch times were able to pick up on the sea coast of about 200 feet altitude the chipped tools which the sea had worn there. It is only in final Stellenbosch or Fauresmith times that the ocean withdrew approximately to its present boundaries.

It has no doubt done so at various times, in the periods of low sea-level, during the Quaternary glacial epochs. It is very probable that tectonic movements played a part in this rhythm, accentuating it at various times, and that, due to these movements, the original levels of deposits and topographical features of the beaches underwent local alterations. Unfortunately, I did not get the opportunity to investigate this aspect of the problem.

Such are the ideas which a too rapid study of the facts in 1929, and again this year, has suggested to me. I would not perhaps have ventured to publish them, had I not mentioned them to your great geologist, Dr. A. L. du Toit, who warmly urged me to do so, presenting them, as is only right, as a working hypothesis. Dr. du Toit did me the honour of accompanying me during several days in the field.

I wish also to thank the various people who helped me to make this all too rapid, but instructive, contact with the complicated and scattered natural evidence. I offer my thanks to Messrs. H. S. Jager, F. Malan and A. J. H. Goodwin and, in the Stellenbosch region, to Dr. Eric Nobbs, without whose records of altitudes my work would have been impossible.

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PLAGES SOULEVÉES A INDUSTRIES LITHIQUES DE LA RÉGION DE KEURBOOMS RIVER, DISTRICT DE KNYSNA, PROVINCE DU CAP.

PAR

G. Mortelmans.

Avec cinq planches.

Debité 3 Juillet 1944.

I Introduction.

Durant un court séjour dans le district de Knysna, à Keurbooms River principalement, j'ai eu l'occasion de faire des observations qui, bien que sommaires, m'ont paru suffisamment intéressantes pour être publiées. L'intérêt de ces observations réside dans l'association de certaines cultures lithiques avec des plages soulevées et d'autres horizons géologiques bien determinés.

II—Morphologie des Environs de Keurbooms River.

Les traits essentiels de la morphologie de ce coin de pays semblent, à première vue, se réduire à l'existence d'une étroite plaine côtière, située au pied d'un plateau remarquablement plan, d'altitude voisine de 500–600 pieds*, et s'étendant jusqu'au pied des Monts Tzitzikama. Toutefois, si l'on examine d'un oeil plus critique les lignes du paysage, on se rend compte que cette simplicité n'est qu'apparente et que d'autres formes, moins bien développées, s'étagent entre ces deux niveaux extrêmes (voir fig. 1).

En effet, montant de la plage vers le plateau l'on traverse successivement:

(a) Une triple ligne de dunes récentes.

(b) Une plaine maritime fertile, située à quelques pieds au-dessus du niveau marin.

(c) Une plage de galets dont la surface est à une altitude voisine de 15-20 pieds.

(d) Ces formations sont séparées des suivantes par un abrupt très marqué conduisant à un premier plateau.

(e) Un étroit plateau, ou plutôt replat d'altitude voisine de 400 pieds, se rattachant par une pente assez douce à

(f) le plateau de 500–600 pieds.

* Les chiffres donnés pour les altitudes des différents horizons sont le résultat de simples appréciations à l'oeil, aussi sont-ils sujets à révision. Ces chiffres toutefois doivent être assez voisins de la réalite ainsi que le suggère l'altitude de points triangulés, sommets du plateau, situés à 632 et 716 pieds.

III—Les Unités Geologiques et Morphologiques.

A.—*Les Dunes Récentes.* Une triple ligne de dunes s'étend, parallèlement à la côte, depuis l'embouchure de la Keurbooms River jusqu'à Keurbooms Strand où elles rejoignent la base du plateau de 400 pieds. Leur altitude maximum est de 150 pieds, au signal situé derrière l'Hôtel Read. Elles sont d'origine récente et je n'y ai fait aucune découverte d'industrie, préhistorique ou autre.

B.—*La Plaine Maritime.* Formant le triangle compris entre le cours inférieur de la Keurbooms River, le cordon de dunes, et l'abrupt peu marqué constituant le pied de la plage de 15–20 pieds, s'étale une plaine, parfois marécageuse, couverte de cultures. Un puits ouvert dans les champs de l'Hôtel Read m'a montré que, sous une faible épaisseur de terre noire, sable riche en matières organiques, s'étalait une plage sableuse, avec coquilles de lamellibranches " in situ "; ce sable a subi un début de calcification.

Le sommet de cette plage est à quelque 5 à 7 pieds au-dessus de la mer.

Le sable noir superficiel contient les restes d'une industrie de Strandloopers, bien développée au site d'habitation n°8 du schèma cartographique (fig. 1).

C.—*La plage soulevée de 15–20 Pieds.* Cette plage, avec les terrasses qui s'y rapportent (du Toit, 1939), a été étudiée en plusieurs points, soit par moi-même (n°1, fig.1), soit par M. M. W. Manson de Johannesburg (n°9 et 11, fig. 1). Elle forme un replat assez bien marqué, dominant la plaine B par un talus de 3 à 6 pieds et s'étendant tout le long de l'abrupt menant au plateau de 400 pieds.

Partout où elle été étudiée, elle a fourni des restes, "in situ ", d'industries lithiques anciennes, plus ou moins usées, se rapportant à des stades primitifs du Stellenbosch du Cap: Stellenbosch A remanié, Stellenbosch B " in situ ".

D.—*Le Replat de 400 Pieds.* Séparé des formations précédentes par un abrupt très marqué, et du plateau de 500–600 pieds par un talus en pente douce, s'étale un replat peu étendu, quoique bien défini.

De part et d'autre de la Keurbooms River, il est entaillé dans les formations peu cohérentes, galets et sables grossiers, des Uitenhage Beds (Crétacé); à l'Est et au Nord, il entame les schistes parfois fossilifères des Bokkeveld Series et les quartzites des Table Mountain Series (Système du Cap).

Ce replat est actuellement profondément disséqué par une série de gorges et de ravins qui ont détruit la majeure partie des sédiments qui y furent déposés. Les lambeaux encore existants suffisent cependant pour se faire une idée assez claire des phénomènes géologiques qui s'y succédèrent.

a.—*Coupe de la route vers Port-Elizabeth.* Quittant la Keurbooms River, la route laisse à gauche une petite carrière montrant la discordance des Uitenhage Beds sur les Bokkeveld Shales (niveau de la plateforme marine pré-Uitenhage), puis s'élève à flanc de colline en entamant ces dépôts Crétacés. Au sommet de la colline, elle entaille de nouvelles formations qui présentent, de haut en bas, la coupe suivante :

(4) Sable noir chargé de matières humiques, peu épais. Middle Stone Age à la base.

(3) Niveau de grenaille latéritique peu épais. Stellenbosch C et D dans la masse.

(2) Niveaux alternant de sols sablo-argileux rouges (dunes?) et de lits de graviers peu volumineux; puissance totale de 1 à 2 mètres.

(1) Uitenhage Beds.

Je ne suis pas certain de l'interprétation à donner au dépôt 2; sans doute faut-il le considérer comme terrasse de 400 pieds de la Keurbooms River ou comme formation d'estuaire se rattachant à la plage de même niveau (n°7 de la fig.1).

b.—*Coupe du Sentier.* Si l'on suit le sentier qui s'élève sur le plateau un peu à l'Est de l'Hôtel Read, on traverse, dans la monteé les mêmes formations conglomératiques que dans la coupe de la route vers Port-Elizabeth, mais, dès que l'on arrive au niveau du replat de 400 pieds, les dépôts superficiels que l'on rencontre sont différents. Sur tout le trajet Ouest-Est du sentier, celui-ci entame des dunes fossiles, dont la coupe est, de haut en bas, la suivante (synthèse des observations faites le long du sentier et dans un donga voisin (n°2 de la fig.1):

(3) Sol sableux noir, peu épais. Middle Stone Age II " in situ ".

(2) Reposant sur 1, mince lit de Middle Stone Age I.

(1) Dune rougie, consolidée, avec niveau inconstant de ferricrete en plaquette. Puissance de la dune : Plusieurs mètres au moins. Stellenbosch C et D disséminés dans toute la masse.

Peu aprés, le sentier s'inflechit vers le Nord-Est, passe dans un col et grimpe la côte qui mène au plateau de 500–600 pieds. Tout le long de cette côte, le ruissellement a décapé la surface gréso-quartzitique du replat, détruisant la stratigraphie des dépôts superficiels qui s'y étendaient, et dont les résidus parsèment le sentier. Un premier affleurement de grès quartzitiques est semé de pièces isolées du Stellenbosch C, que leur teinte ferrugineuse montre provenir, soit d'une dune disparue, soit du niveau de grenailles latéritiques (n°3 du croquis).

Le sentier passe ensuite sur une série d'affleurements des mêmes grès, et, immédiatement après le passage d'une porte de clôture, on trouve, épars sur ces grès, de volumineux galets

fort bien roulés, mêlés aux éluvions provenant de ces grès (n°4 du croquis). Plus aucune observation précise n'est possible, ces galets n'étant plus que le résidu, plus ou moins en place, d'une formation détruite par le ruissellement. Etant donné l'uniformité du calibre et la perfection du roulis des galets, je pense qu'il faut les considérer comme résiduels de la plage qui couvrait le plateau de 400 pieds. Mêlées à ces galets, se rencontrent plusieurs industries lithiques, dont une se présente dans le même état physique que les galets: le Stellenbosch A.

Je pense qu'il faut interpréter le replat de 400 pieds comme une plateforme d'abrasion marine érodée en bordure du plateau de 500–600 pieds, à une époque où celui-ci avait subi un premier, mais peu important mouvement de relèvement. La vallée de la Bito, affluent de droite de la Keurbooms River, offre, dans le paysage, un replat dont l'altitude me paraît voisine.

E.—Le Plateau de 500-600 Pieds. Raccordé au précédent par une pente assez douce, le plateau de 500–600 pieds s'étale, remarquablement plan, jusqu'au pied des Monts Tzitzikama. Sa surface, là où je l'ai foulée, est partout constituée par le niveau de grenaille latéritique précédemment reconnu, riche en outillage des Stellenbosch C et D.

Localement, une faible épaisseur de sol noir sableux recouvre l'horizon latéritique.

Ce tableau s'étend, à des altitudes variables, tout le long de la côte Sud depuis East London jusqu'au Cap. Son âge est assez bien déterminé, il entaille en effet, outre les formations anciennes, les dépôts Crétacés du type Uitenhage Beds, et est, en certains points, encore couvert de lambeaux des Alexandria Formations, dépôts marins dont l'âge va de l'Eocène supérieur au Mio-Pliocène (33, p. 417). On peut en déduire que l'abrasion de cette plateforme par la mer se place aux temps Crétacé final—début Eocène, et que son relèvement et son intégration au subcontinent sont d'âge Pliocéne supérieur, sinon Pléistocéne ancien.

IV Description Succincte des Industries Lithiques

En l'absence d'une étude détaillée du Stellenbosch du Cap comparable à celle du Stellenbosch du Vaal (9) je considérerai les groupes suivants:

A.—*Groupe Pré-Stellenbosch?* A l'état remanié dans la plage de 15—20 pieds?

B.—*Groupe Stellenbosch,* aves les subdivisions qui suivent:

Stellenbosch A: " in situ " dans la plage de 400 pieds; remanié dans le plage de 15–20 pieds; remanié dans l'horizon latéritique des plateaux.

Stellenbosch B: " in situ " dans la plage de 15–20 pieds.

Stellenbosch C et D: " in situ " dans l'horizon latéritique des plateaux et les dunes correspondantes.

Stellenbosch E: en surface des formations plus anciennes.

C.—*Groupe Middle Stone Age*: en surface de la dune Stellenbosch et dans la terre noire la surmontant.

D.—*Groupe Later Stone Age*: en surface de toutes les autres formations.

A.—GROUPE PRÉ-STELLENBOSCH.

Au point n°9 du croquis, M. M. W. Manson a trouvé, dans une petite carrière ouverte dans les graviers de la plage de 15—20 pieds, deux pièces douteuses, extrêmement roulés.

Il s'agit de deux galets dont l'un, à premiére taille très usée, paraît utilisé à la pointe à une date un peu moins ancienne, alors que l'autre présente quelque ressemblance avec un très grossier coup-de-poing cordiforme obtenu par l'enlèvement alterne de quelques éclats délimitant la pointe. Le roulis subi par ces " pièces " est tel qu'il n'est pas possible de se prononcer avec certitude: peut-être ne s'agit-il que de taille marine. Un plus grand nombre de pièces serait en tout cas nécessaire pour se faire une opinion.

S'il s'agit réellement d'une industrie de type pré-Stellenbosch, elle doit être antérieure au façonnement du replat de 400 pieds et au dépôt de la plage correspondante, qui contient, à l'état déjà roulé, l'industrie Stellenbosch A. Certaines observations faites dans les environs du Cap et près d'East-London (8) semblent indiquer l'existence de " Pebble-Culture " à la côte sud; aussi ne me semble-t-il pas impossible qu'une industrie analogue puisse se rencontrer dans le bassin de la Keurbooms River. A mon sens, cette industrie pourrait se retrouver dans de très vieux graviers, à la surface du plateau Pliocène de 500—600 pieds.

B.—GROUPE STELLENBOSCH.

I.—Stellenbosch A. Je classe sous cette dénomination le matériel, plus ou moins roulé, qui se rapporte à la plage de 400 pieds.

Il existe:

(a) " in situ," mêlé aux galets provenant de la désagrégation de cette plage (n°4 du croquis), et présentant le même aspect physique que les galets;

(b) remanié dans la page de 15–20 pieds (n°1, 9 et 11 du croquis);

(c) remanié dans le niveau latéritique des plateaux (n°3 et 7).

A.—STELLENBOSCH A DE LA PLAGE DE 400 PIEDS.

Des différences d'usure assez marquées et la présence de doubles patines permettent de séparer ce matériel en deux séries I et II.

Série I.: Cette série comporte 6 coups-de-poing et 5 éclats, fortement roulés; des restes d'un très vieux ferricrete (concrétions et couleur brune) se retrouvant sur plusieurs pièces, alors que d'autres ont été décolorées.

Coups-de-poing: La technique employée dans la confection de ces instruments peutêtre définie comme Abbevilienne taille sur enclume de volumineux galets par départ alterne de gros éclats remontants, en utilisant comme plans de frappe successifs les négatifs des premiers éclats.

1. Le type le plus élémentaire ne comporte l'enlèvement biface d'éclats que sur un bord du galet. Dimensions. 17 x 13 x 6,7 cms. figures 2a et 2b.

2. Mieux fini est un volumineux coup-de-poing taillé suivant la même technique, qui s'exerce cette fois sur les deux bords longs opposés; la base du galet est réservée et la section générale est lozangique. Dimensions: 19,5 x 10.5 x 6,9 cms. Figures 3a et 3b.

3.—4. Coups-de-poing de même type que le précédent mais moins bien faits, avec talon réservé; ces deux pièces témoignent d'une retaille plus récente de la pointe. Dimensions: 16 x 7,5 x 6,7 cms. et 14 x 7,5 x 5,7 cms.

5. Coup-de-poing de dimensions réduites montrant l'existence des tailles successives I et II; la taille I est fortement usée; la taille II l'est encore, quoique faiblement. En outre la pointe en a été abattue beaucoup plus récemment (Strandloopers?) pour en faire une sorte de grattoir-museau.

6. Pièce particulière rappelant les coups-de-poing, dont une face est constituée par une calotte de galet, tandis que l'autre est taillée à grands éclats. Dimensions: 10 x 6,8 x 3,8 cms.

Éclats: Éclats grossiers, épais, de type Clactonien de largeur et longueur voisines de 6 à 8 cms. Leur état de roulis ne permet pas d'y reconnaître d'utilisation ou de retouches secondaires; peut-être représentent-ils simplement les déchets de taille sur enclume conduisant des galets aux coups-de-poing. Un exemple est représenté par les figures 4a et 4b.

Série II.: Cette série présente une usure moins forte que la précédente; les arêtes sont plus fraîches, quoique non tranchantes.

Coups-de-poing: 1. Le premier est une pièce sur galet, utilisant la même technique Abbevilienne que dans la sérieI; une partie de la surface primitive du galet est conservée. Dimensions: 13 x 8,5 x 5,7 cms.

2. Le second est une pièce de petite dimension complètement défigurée par des retailles ultérieures.

Éclats: Ceux-ci comportent:

(1) un éclat de facture Clactonienne assez frais;

(2) un éclat sur calotte de galet, d'état physique I, avec retaille de patine II en une sorte de grossier perçoir.

Pièce Douteuse: Pièce ressemblant à un petit nucleus Middle Age, mais que l'état d'usure me fait ranger dans la série II.

B.—STELLENBOSCH A REPRIS DANS LA PLAGE DE 15–20 PIEDS.

Parmi les pièces recueillies " in situ " dans les graviers de la plage de 15–20 pieds se recontre une série d'instruments et d'éclats que leur état d'usure, leur état physique ferritisé, et leur technique me font rapporter au matériel de la plage de 400 pieds dont ils seraient descendus.

Gisement n°1 du Croquis: Ce gisement m'a fourni deux pièces très usées et incrustées de ferricrete.

(1) La première est une sorte de " pic-coup-de-poing " uniface sur grand éclat à bulbe de base; cet éclat a été obtenu en décalottant l'extrémité d'un volumineux galet, puis en se servant du plan ainsi obtenu comme plan de frappe. L'angle entre la plateforme et le plan de l'éclat est voisin de 120°; le bulbe a été partiellement enlevé par de grossières retouches. Dimensions: 21 x 12,5 x 4,5 cms. (Fig. 5a et 5b.)

(2) Eclat extrêmement roulé, à double patine, la seconde patine étant celle du Stellenbosch B propre à la plage.

Gisement n°9 du Croquis: Ce gisement est constitué par une carrière ouverte dans un petit golfe de la plage de 15–20 pieds. Il a fourni à M. M. W. Manson un matériel complexe parmi lequel se trouve une pièce que je range dans la série Stellenbosch A.

C'est une pièce sur galet, très roulée, montrant une taille élémentaire analogue à celle des outils de la plage de 400 pieds; après roulis elle a été entièrement retaillée au Stellenbosch B et si déformée qu'il est impossible d'en définir le type primitif. La retaille B est elle-même un peu roulée.

Gisement n°11 du Croquis: L'affleurement de la plage de 15–20 pieds au pied d'un " Elephant Path " a forum à M. M. W. Manson une pièce " in situ ", gros éclat Clactonien à usure marine.

C.—STELLENBOSCH A REPRIS DANS LE NIVEAU LATÉRITIQE DES PLATEAUX.

Deux pièces latéritisées provenant de ce niveau présentent l'usure et la technique du matériel de la plage de 400 pieds; on peut les considérer comme des pièces de cette époque, restées en surface du replat et incorporées ultérieurement dans le niveau latéritique lors de sa formation.

1. La première provient du gisement n°3. C'est un grossier " pic-coup-de-poing " uniface trièdre semblable à celui de la

figure 5 et de technique identique; décalottage primaire d'une extrémité de volumineux galet de manière à former un plan de frappe, enlèvement d'un volumineux éclat de facture Clactonienne, enlèvement sur celui-ci de deux gros éclats remontants utilisant la surface de l'éclat comme plan de frappe et conduisant à la forme pic en dégageant la pointe. Ce outil porte des concrétions latéritiques; il a subi un fort roulis dans la plage, puis ultérieurement une carie éolienne. Dimensions: 19,5 x 12,5 x 4,8 cms. Figures 6a et 6b.

2. La seconde pièce provient du gisement n°7, à la base de l'horizon de grenailles latéritiques. C'est un cleaver de forme primitive, constitué d'un éclat latéral de galet; un large éclat primaire, antérieur au départ de l'éclat constituant le cleaver, a délimité le tranchant utile; la retaille grossière et remontante d'un bord de l'éclat donne la forme allongée de l'outil, tandis que l'autre bord est constitué par le galet. Cette pièce est trés usée, à la fois par roulis et usure éolienne. Dimensions: 18,5 x 11 x 5 cms. Figures 7a et 7b.

II—Stellenbosch B.

Je classe sous cette dénomination les pièces à faible usure recueillies par moi-même et par M. M. W. Manson " in situ " dans les graviers de la plage de 15–20 pieds. Quoique peu nombreuses, ces pièces sont très caractéristiques et répondent à la définition de la " Technique de Tachengit ".

Nuclei: Un nucleus à éclats, assez grossier, provient du gisement n°9. Il a donné une série d'éclats de facture Clactonienne, très remontants; le plan de frappe est tantôt constitué par la surface du galet, tantôt par la concavité produite par l'enlèvement d'un premier éclat. Son aspect général est celui d'un coup-de-poing mal venu. Dimensions: 14 x 11 x 5 cms. Figures 8a et 8b.

Cette pièce se laisse assez étroitement comparer avec les nuclei de " Technique de Tachengit " décrite par A. J. H. Goodwin (5) des environs du Cap.

Eclats: 1. Ce même gisement a donné un grand éclat Clactonien s'accordant bien, techniquement, avec le nucleus décrit-ci-dessus. Le bulbe est assez peu marqué; le plan de frappe est légèrement concave et représente la plus grande partie de la concavité produite sur le nucleus par l'enlèvement d'un premier éclat. Dimensions: 13 x 14,5 x 3,2 cms. Figures 9a, 9b et 9c.

2. Le gisement n°1 m'a donné un large éclat épais, produit du débitage latéral d'un galet. Le bulbe a été enlevé par une série de retouches, suivant la technique de Tachengit. Dimensions: 17 x 11,5 x 5,7 cms.

Coups-de-poing: Le gisement n°1 m'a donné un très beau coup-de-poing uniface sur éclat oblong épais; la face supérieure est entiérement retaillée depuis les bords, base exceptée; la face

inférieure est constituée par le plan d'éclatement dont le bulbe latéral a été enlevé par une série de larges facettes assez plates suivant la technique de Tachengit. Dimensions: 21 x 10 x 6 cms. Figures 10a, 10b et 10c.

III—STELLENBOSCH C.

Me fondant à la fois sur l'état physique et sur l'évolution de la technique, j'ai subdivisé en deux le matériel propre au niveau de grenailles latéritique des plateaux: Stellenbosch C et Stellenbosch D.

Toutes ces pièces sont brunies par le milieu où elles ont séjourné; celles du groupe C ont en outre subi, avant la latéritisation, une certaine usure éolienne.

Coups-de-poing: Tous les coups-de-poing semblent être sur éclats de galets; plusieurs sont de très grandes dimensions. Tous sont caractérisés par une taille large et assez plate.

1. Le plus typique et le mieux fini est un grand coup-de-poing sur large éclat à bulbe de base; la taille est à grandes facettes plates et le tranchant est rectiligne; le revers garde une portion de la surface primitive du galet, à la base et dans la partie médiane. Cette pièce provient du gisement n°3. Dimensions: 27 x 14 x 6,5 cms. Figures 11a et 11b.

2. Du même gisement provient un coup-de-poing de même type, moins fini, à talon de galet partiellement conservé; la taille est, comme dans le précédent, à grands éclats plats, utilisant comme plan de frappe, tantôt la surface du galet, tantôt les négatifs produits par l'enlèvement de premiers éclats. Dimensions: 25 x 16,5 x 8,5 cms.

3. Un autre, provenant du gisement n°7, présente les dimensions suivantes: 18,5 x 10,6 x 5,5 cms.

4. Provenant de la dune fossile au point n°2, est un coup-de-poing formé d'un grand éclat à bulbe latéral de base, soigneusement taillé à grands éclats plats sur les deux faces. La pointe en a été retaillée ultérieurement, au Stellenbosch D, dont elle a la patine. Dimensions: 20 x 12,5 x 4,5 cms.

5. Provenant du gisement n°4 est un coup-de-poing sur éclat latéral de galet; la taille, assez courte, est comparable à celle des cleavers sur éclats latéraux du Stellenbosch III de la vallée du Vaal; elle part sur chaque face du bord gauche, tranchant d'un côté, enlevant la bulbe de l'autre; la section transverse qui en résulte est un parallélogramme. Quelques tailles de régularisation existent également à la base. La pointe en a été brisée ultérieurement. Dimensions: 14 x 10 x 4,9 cms.

6. Un autre coup-de-poing, sur éclat de base cette fois, provient de la dune n°2; sa base de galet est conservée. Dimensions: 13 x 9,5 x 3,7 cms.

7. Un autre, descendu du niveau de latérite, gisait sur la plage de 15–20 pieds au gisement n°1.

Toutes ces pièces ont subi une légère usure et carie éoliennes avant d'être soumises à l'influence du milieu latéritique du Stellenbosch D. Une piece à double patine C+D montre le bien fondé de cette subdivision.

L'aspect général de cette industrie rappelle plus ou moins le Stellenbosch *III* et même *IV* de la vallée du Vaal.

IV—Stellenbosch D.

Cette série comporte des pièces brunies par le ferricrete, toujours fraîches, avec en plus un très poli éolien.

Coups-de-poing sur galets: Certaines pièces, simplement ébauchées, montrent que le stade initial de la taille reste, comme dans les groupes précédents, une taille sur enclume; à ce stade Abbevilien succède une technique de finissage au rondin de bois donnant naissance à des produits de réelle beauté, comparables aux plus belles pièces des Stellenbosch *IV* et *V* du Vaal ou de l'Acheuléen évolué français. La retouche est plate, régulière, et la section lenticulaire aplatie. Un exemple est figuré dans les dessins 12a et 12b.

Coups-de-poing sur éclats: Certains coups-de-poing sont faits sur de gros éclats qui pourraient provenir de nuclei, mais le fini de la retaille a pratiquement effacé les caractères primitifs de l'éclat.

Les dimensions moyennes des pièces classées dans ces deux catégories sont: 18 x 10 x 5 cms.

Coups-de-poing sur fragments de roche: Une pièce, très particulière, est faite sur un fragment de grès à section triangulaire aplatie: les bords de la pièce sont taillés et avivés à retouches assez abruptes, quoique poignées, abattant les angles du triangle; une extrémité est façonnée en tranchant de hache par retaille biface; l'autre bout est transformé en burin par une quadruple retaille: deux éclats obliques déterminent le tranchant du burin, suivis de l'enlèvement sur les plans de deux éclats perpendiculaires aux premiers, limitant le diamètre du tranchant du burin. Dimensions: 21,5 x 10 x 4,5 cms. Figures 13a et 13b.

Éclats: Provenant de différents points, j'ai ramassé quatre éclats: tous sont des éclats latéraux, de type proto-Levallois, à plan de frappe plus ou moins bien préparé. Ils proviennent donc de nuclei préparés. Le débitage garde toutefois une saveur Clactonienne en ce sens que l'angle entre le plan de frappe préparé et le plan d'éclatement est très ouvert et compris entre 110° et 130°.

Certains de ces éclats sont retouchés ou usagés. Un exemple, de dimensions 5,5 x 10,5 x 2,2 cms. est représenté dans les figures 14a, 14b et 14c.

V—Stellenbosch E.

Je range sous cette dénomination des pièces de type Stellenbosch très évolué, voire même Fauresmith inférieur, fraîches,

non colorées par du ferricrete, ramassées en surface de la plage de 15—20 pieds (gisements n°1 et 11), sur les pentes entre les gisements n°11 et 10,et en bordure du plateau de 400 pieds (gisement n°10).

1. Le gisement n°1 m'a fourni des éclats frais atypiques.

2. Au point n°11, à la surface de la plage et au pied d'un " Elephant Path ", M. M. W. Manson a observé un volumineux nucleus qui, à la description, semble de type Levallois.

3. Sur la pente, le long de cet " Elephant Path ", il a ramassé deux éclats de facture Clactonienne, de taille moyenne, et deux éclats Levallois, longs de 7 et 10 cms.

4. Au point n°10, il a recueilli deux éclats: le premier est grand, de type Clactonien, le second est un magnifique éclat Levallois triangulaire allongé, à bulbe peu marqué et plan de frappe à grandes facettes. Ses dimensions sont: 26,5 x 11 (base) x 3 cms.

Ces pièces trop peu nombreuses, peuvent représenter un stade final du Stellenbosch, ou même un équivalent du Fauresmith.

Caractères généraux et affinités du Groupe Stellenbosch.—Au cours de l'évolution du Groupe Stellenbosch de la Côte Sud, le matériel initial reste le même: galets de quartzite ou de grès quartzitique provenant généralement des Table Mountain Series. Cette identité de matériel différencie cette évolution de celle du Stellenbosch de la vallée du Vaal où l'on a la succession quartzites-laves-indurated shales. On peut cependant, à titre d'hypothèse de travail, tenter de dégager, malgré l'insuffisance numérique du matériel, les lignes générales de cette évolution et esquisser une comparaison avec le Stellenbosch de la vallée du Vaal; toutefois, les analogies observées n'impliquent pas nécessairement un étroit synchronisme.

1. *Stellenbosch A*.—L'examen du matériel propre à la plage de 400 pieds montre l'existence de deux séries I et II, de roulis différent, dont la réalité est prouvée par l'existence de doubles patines I+II; le matériel recueilli est toutefois insuffisant pour séparer ces deux séries d'après la technique qui semble la même.

Ce matériel comporte, à côté de coups-de-poing obtenus par taille Abbevilienne de gros galets sur enclume, des pièces unifaces, sortes de pics-coups-de-poing, sur gros éclats de Clacton, et des éclats plus ou moins volumineux de même technique.

Le débitage paraît très simple, la seule préparation étant le décalottage de l'extrémité du galet pour obtenir un plan de frappe.

L'association de ces deux facies, à coups-de-poing et à éclats, permet de définir l'industrie comme étant de type Clacto-Abbevillien.

Cette industrie se laisse fort bien comparer au Stellenbosch I de la terrasse de 50 pieds du Vaal à Vereeniging. Il est à

souligner que de part et d'autre le matériel est le même galets de quartzite de propriétés physiques fort voisines.

Le Stellenbosch du Groupe A correspond dans son ensemble aux stades 1 et 2 de A. J. H. Goodwin (5), définis comme suit: "1. A stage, best represented by the Somme Chellean, in which flint nodules, or simple river pebbles, were trimmed to shape (Abbeville technique).

"2. Probably a variant of this, but more widespread in areas where suitable small pebbles were absent, is the use of a large flake struck from an untrimmed river boulder."

2. *Stellenbosch B.*—Si, numériquement, le matériel de la plage de 15–20 pieds semble peu intéressant, l'apparition d'une technique nouvelle, la " technique de Tachengit ", lui donne de l'importance. Cette technique est un développement du stade précédent dans lequel le bulbe est enlevé; elle est caractérisée de la manière suivante par A. J. H. Goodwin (5): "3. The use of a large rock fragment as a core from which several flakes were struck. A simple platform was prepared by the removal of large flakes, or the whole conformed to the shape of a rough coup-de-poing. The bulb of percussion was often removed from the resulting implement by a number of trimming blows, though in some cases the striking platform is more carefully prepared. (Tachengit technique.) . . ." A cette définition correspond bien le matériel recueilli: nucleus sur fragment de roche (ou gros galet?), éclats de base ou latéraux de base, outils formés en retaillant la face supérieure de l'éclat, alors que le plan d'éclatement reste lisse, à l'exception du bulbe qui est enlevé par quelques retailles.

Je n'ai pas trouvé de coups-de-poing sur galet; je crois cependant que ces formes doivent coexister avec celles sur éclats, car elles se retrouvent au stade D.

3. *Stellenbosch C.*—L'existence de ce groupe est prouvée par une usure et carie éoliennes propres antérieure à la patine ferrugineuse de Stellenbosch D qui s'y superpose, ainsi que par la présence d'une pièce à double patine C+D.

Cet outillage est caractérisé par des coups-de-poing, souvent de grandes dimensions, taillés à grand éclats plats; ils semblent en général faits sur éclats; une ou deux pièces pourraient cependant avoir été façonnées sur des galets aplatis. Une portion de la surface du galet primitif est souvent conservée à la base.

Cette industrie se laisse comparer, au moins superficiellement, au Stellenbosch *III*, et peut-être *IV* du Vaal.

4. *Stellenbosch D.*—Ce groupe est propre à l'horizon latéritique des plateaux et aux dunes marginales qui s'y rapportent. L'examen du matériel montre, qu'à côté de coups-de-poing Acheuléens sur galets, existent des coups-de-poing sur éclats; une préparation du nucleus existait, attestée par l'existence d'éclats latéraux à plan de frappe préparé, sorte de Proto-Levallois. L'examen de formes ébauchées offre un premier stade Abbevillien sur enclume, suivi d'un stade Acheuléen de finis-

sage au bois. Une pièce particulière, sorte de hache-burin sur fragment de roche, se laisse comparer aux formes analogues du Stellenbosch *V* du Vaal.

5. *Stellenbosch E.*— L'homogénéité industrielle des pièces rangées sous cette dénomination n'est pas certaine, celles-ci ayant été ramassées en surface des formations plus anciennes: toutefois elles sont fraîches et ont leur teinte naturelle. Elles comportent des éclats de facture Clactonienne et des éclats Levallois, ces deux catégories provenant de nuclei façonnés. La description d'un nucleus observé par M. M. W. Manson est celle d'un volumineux nucleus Levallois.

Ce matériel peut représenter un stade final du Stellenbosch avec développement de la technique Levallois, mais est peut être un équivalent du Fauresmith qui n'a pas été observé avec certitude à la Côte Sud.

En résumé, au cours de cette évolution, l'unité de matériel (galets de quartzite) détermine une unité de technique simple (coups-de-poing par débitage Abbevilien de galets) à laquelle s'associe une succession d'industries à éclats passant par les stades Clactonien, Tachengit, Proto-Levallois et Levallois.

C.—Groupe Middle Stone Age.

Un certain nombre de pièces, typologiquement Middle Stone Age, a été ramassé en surface, principalement au gisement n°1 (nucleus discoïde aplati d'un diamètre de 9,5 cms.) et au gisement n°4 (pointes, disques nuclei, etc.), mêlé à des industries plus anciennes.

Le même matériel lithique a été retrouvé " in situ ", occupant deux niveaux stratigraphiquement bien déterminés au dessus de la dune Stellenbosch du gisement n°2.

Série Middle Stone Age I.—L'outillage constituant cette série se rencontre, à l'état dispersé, sur la surface d'érosion de la dune Stellenbosch, sous le sable noir qui la surmonte. Les pièces sont teintées sur les deux faces par le ferricrete. Le matériel recueilli comporte: un nucleus discoïde aplati; trois éclats Levallois allongés, de dimensions voisines de 5,5 x 4 cms.; sept pointes triangulaires non retouchées (une seule présente quelques traces de travail secondaire) de dimensions moyennes comprises entre 5 et 7 cms.; une lame sur angle de nucleus simulant une lame à dos abattu.

Série Middle Stone Age II.—Cette série se trouve dispersée dans la couche de sable noir qui surmonte la dune Stellenbosch. Les pièces ont gardé la teinte propre du quartzite dont elles ont été taillées.

Le matériel recueilli comporte: des éclats et des petites lames, tantôt à plan de frappe préparé, tantôt lisse; afin de diminuer l'épaisseur de la base, dans le but probable de faciliter l'emmanchement, l'arête médiane à la face supérieure de l'éclat

a parfois été abattue par une taille axiale partant de plan de frappe.

Si, au point de vue stratigraphique, il semble que l'on ait affaire à deux niveaux distincts, il n'est pas possible de séparer typologiquement le matériel que en provient. Ce matériel me paraît ne former qu'une seule industrie en rapport étroit avec la "Variation de Mossel Bay" du Middle Stone Age, dont elle présente les caractéristiques essentielles (6):

"1. Primary stepped flake on the upper surface of flakes . . . suggested as deliberate, even possibly to facilitate hafting.

"2. Tools broad in relation to their length.

"3. Simplicity of secondary work and abundance of tools without secondary trimming."

L'outillage des deux séries I et II répond fidèlement à ces définitions; peut-être faut-il considérer la série II comme dérivée de la première, et décolorée par l'action réductrice d'un milieu riche en matières organiques.

D.—Groupe Later Stone Age.

Je dois à l'obligeance de M. Read, propriétaire de l'Hôtel Read, la connaissance d'un intéressant site d'h[illegible]tion, riche en restes de l'industrie des Strandloopers; ce g[illegible] porte le n°8 sur la figure 1, et est situé au pied des du[illegible] récentes, de part et d'autre du sentier qui va de l'hôtel à l'océan.

On ramasse abondamment dans les labours: des meules, molettes, pilons, kwés, perçoirs à kwés, pierres à rainure pour façonner les aiguilles et poinçons en os, éclats grossiers, pseudo-coups-de-poing, etc., le tout en quartzite ou grès quartzitique; des tessons de poterie parfois avec " têton " percé d'un trou de suspension vertical; de nombreux restes de repas, os, dents et coquilles.

Des pièces isolées, se rapportant à la même culture se retrouvent un peu partout, en surface des formations plus anciennes, faites souvent de pièces reprises aux outillages plus anciens, Stellenbosch ou Middle Stone Age; au gisement n°4 j'ai recueilli deux pièces en phyllade; l'une est un grattoir épais, fréquemment ravivé; l'autre semble une ébauche de percoir à kwé. De toute la succession industrielle, ce sont les deux seules pièces qui ne soient pas en quartzite ou grès quartzitique.

V.—Conclusions.

La mise en parallèle des phénomènes géologiques observés et des industries associées permet, sinon de tirer des conclusions stables—les données sont encore par trop insuffisantes—du moins de faire une série de suggestions qui permettent d'émettre une bonne hypothèse de travail.

1. A la fin du Crétacé et durant la partie inférieure de l'Eocène, la mer a découpé, à l'emplacement actuel de la Côte

Sud, une large plate-forme continentale sur laquelle elle a déposé subséquemment des formations marines, les Alexandra Formations d'âge Eocène supérieur à Mio-Pliocène.

2. D'importants mouvements de relèvement du sub-continent se sont produits à une époque qui est généralement considérée comme Pliocène supérieur, mais qui pourrait, à mon sens, être Pléistocène tout à fait inférieur, si, comme je le suppose, on trouvait sur cette plateforme des industries de type pré-Stellenbosch. La plage de 400 pieds, érodée en conséquence directe de ces mouvements tectoniques, contient en effet, à l'état déjà roulé, une culture lithique de type Stellenbosch A.

L'amplitude de ce premier relèvement ne me paraît pas, à Keurbooms River du moins, avoir été très forte, au plus 100 à 150 pieds.

3. Cette vue est fondée sur le fait que la plateforme marine suivante, actuellement élevée à quelque 400 pieds, a étê découpée à environ 100 ou 150 pieds en contrebas de la précédente. La mer y déposa des dépôts de plage comportant, à l'état roulé, une industrie dont je fais le type de mon Stellenbosch A et qui est voisine, sinon identique, du Stellenbosch I de la terrasse de 50 pieds du Vaal à Vereeniging.

4. Ces dépôts sont interrompus par un important mouvement de relèvement du sub-continent, qui amène cette plage à une altitude voisine de 400 pieds. A mon sens, un mouvement de cette amplitude n'a pu se produire sans mouvements similaires à l'intérieur du continent, et l'on peut se demander si le creusement du Vaal, depuis la terrasse de 50 pieds à Vereeniging jusqu'à son thalweg n'est pas dû, en ordre principal, plus à ces répercussions tectoniques qu'à des oscillations climatiques. Cette vue serait corroborée par l'existence dans la terrasse de 50 pieds du Vaal et dans la plage de 400 pieds à Keurbooms River d'industries de même type. Il est intéressant de souligner que, dans une note très récente, l'Abbé Henri Breuil (1) interprète également les graviers de 50 pieds à Vereeniging comme graviers se rattachant aux vieux graviers du Vaal et antérieurs aux mouvements tectoniques qui ont forcé la rivière à approfondir son lit aux dépens des bancs diabasiques qui en constituaient le fond jusqu'alors.

Pour en revenir à Keurbooms River, il est possible que cette émergence ait été accompagnée d'un climat semi-aride amenant la formation de ferricrete cimentant la vielle plage et dont les restes se retrouveraient sous forme de concrétions sur l'outillage et les galets.

5. Ce mouvement a dû être relativement rapide, et, au moins ici, sans périodes d'arrêt conduisant à des paliers intermédiaires. L'ancienne falaise, front de l'érosion marine subséquente, est admirablement bien marquée dans le paysage par un abrupt qui s'étend, sans interruption, depuis la côte de 20 pieds jusqu'à celle de 400.

Le creusement en gorge des cours d'eau, conduit aux mêmes conclusions.

6. Au cours de cette nouvelle période d'érosion, la mer a déposé des graviers de plage auxquels se raccordent les terrasses de la Keurbooms River; ces dépôts sont datés par une industrie très typique, dont je fais le type de mon Stellenbosch B et qui est caractérisée par l'emploi de la technique de Tachengit.

7. A une période indéterminée, qui est peut-être intermédiaire entre les stades industriels des Stellenbosch B et C, mais, qui peut-être correspond à la faible émersion Middle Stone Age, ces graviers sont portés à 15–20 pieds au dessus de l'actuel niveau marin.

8. La carie et l'usure éoliennes que montrent les pièces du Stellenbosch C laissent entrevoir, après le Stellenbosch B, la possibilité d'une période de pénéplanation éolienne. Cette vue toutefois demande des observations plus précises pour être, ou confirmée, ou infirmée.

Rappelons que, typologiquement, cette industrie se laisse rapprocher des Stellenbosch III et IV de la vallée du Vaal.

9. Durant le stade de développment industriel qui suit le Stellenbosch D, il semble qu'ait prévalu un climat de type semi-aride, auquel se rapporte la formation de l'horizon de grenailles latéritiques qui couvre les deux plateaux, ainsi que les dunes ferritisées qui bordent le replat de 400 pieds, face à la mer. Typologiquement, l'industrie Stellenbosch D paraît voisine du Stellenbosch V du Vaal.

10. Le stade industriel suivant, le Stellenbosch E, se retrouve en surface de dépôts plus anciens. On peut se demander s'il ne correspond pas à une phase plus humide accompagnée d'une certaine érosion.

11. Une nouvelle oscillation vers l'aridité pourrait être indiquée par la ferritisation du matériel Middle Stone Age. C'est à cette époque sans doute que se place la formation de la plage sableuse que de faibles mouvements de relèvement amènent à la côte de 5–7 pieds.

12. La terre noire qui contient le Middle Stone Age II, sans doute remanié du stade précédent, et les restes de la culture des Strandloopers, représenterait la période actuelle d'érosion et de sédimentation, image d'une nouvelle oscillation vers un climat plutôt humide.

VI.—Remerciements.

Je ne voudrais pas terminer cette étude sans profiter de l'occasion qu'elle me fournit pour remercier tous ceux qui, en Afrique du Sud, ont mis si généreusement leur science à ma disposition ou m'ont fait profiter de leur connaissance du terrain; parmi eux je tiens à remercier tout spécialement:

Monsieur le Professeur C. van Riet Lowe, Directeur de l'Archaeological Survey, pour m'avoir si aimablement offert l'hos-

pitalité dans le Service qu'il dirige et m'avoir fait participer à sa grande science de la Préhistoire Africaine.

Monsieur l'Abbé Henri Breuil, pour le précieux enseignement dont il m'a si généreusement gratifié.

Monsieur B. D. Malan, pour son aide de tous les instants pendant mon séjour à l'Archaeological Survey.

Enfin, dans le cadre plus restreint de cette étude, Monsieur M. W. Manson, Ingénieur aux S.A.R., et Monsieur Read, propriétaire du Read's Hotel à Keurbooms River, pour leur adie sur le terrain.

Keurbooms River, Décembre 1944. Johannesburg, Janvier 1944. Elisabethville, Mai 1944.

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TEXTE SE RAPPORTANT AUX PLANCHES SUIVANTES.

Planche 1.—Figure 1 a. Croquis topographique des environs de Keurbooms River.

A.—Replat de 500–600 pieds; B.—Replat de 400 pieds; C.—Dunes fossiles; D.—Plage de 15–20 pieds; E.—Plage de 5–7 pieds; F.—Dunes récentes; G.—Plage actuelle.

Planche 1.—Figure 1 b. Coupe suivant X-Y de la figure 1 a.

1.—Replat de 500–600 pieds; 2.—Replat de 400 pieds; 3.—Dunes fossiles; 4.—Plage de 15–20 pieds; 5.—Plage de 5–7 pieds; 6.—Dunes récentes; 7.—Plage actuelle; 8.—Niveau marin.

Planche 2.—Figures 2–3–4: Stellenbosch A.

Planche 3.—Figures 5–6–7: Stellenbosch A.

Planche 4.—Figures 8–9–10: Stellenbosch B.

Planche 5.—Figure 11: Stellenbosch C. Figures 12–13–14: Stellenbosch D.

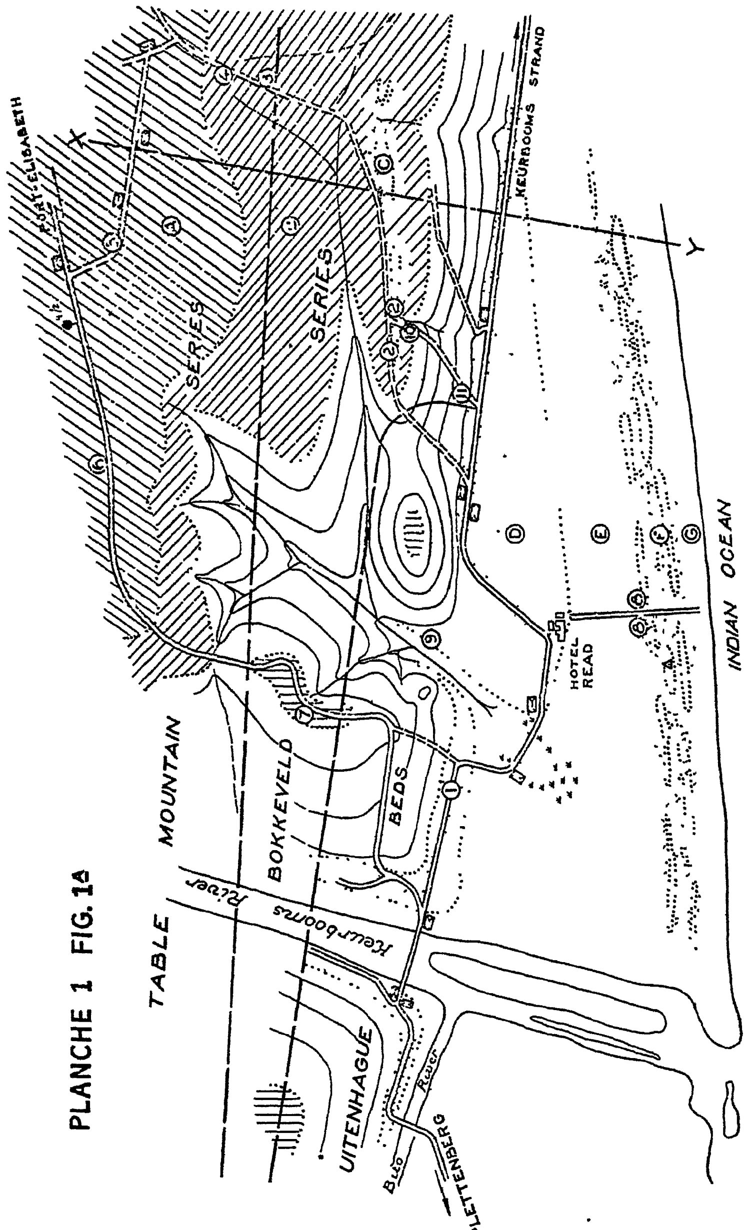
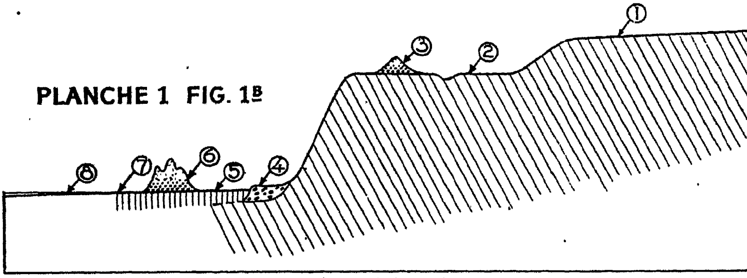


PLANCHE 1 FIG. 1a

PLANCHE 1 FIG. 1B



Section X-Y (Fig. 1a).

PLANCHE 2

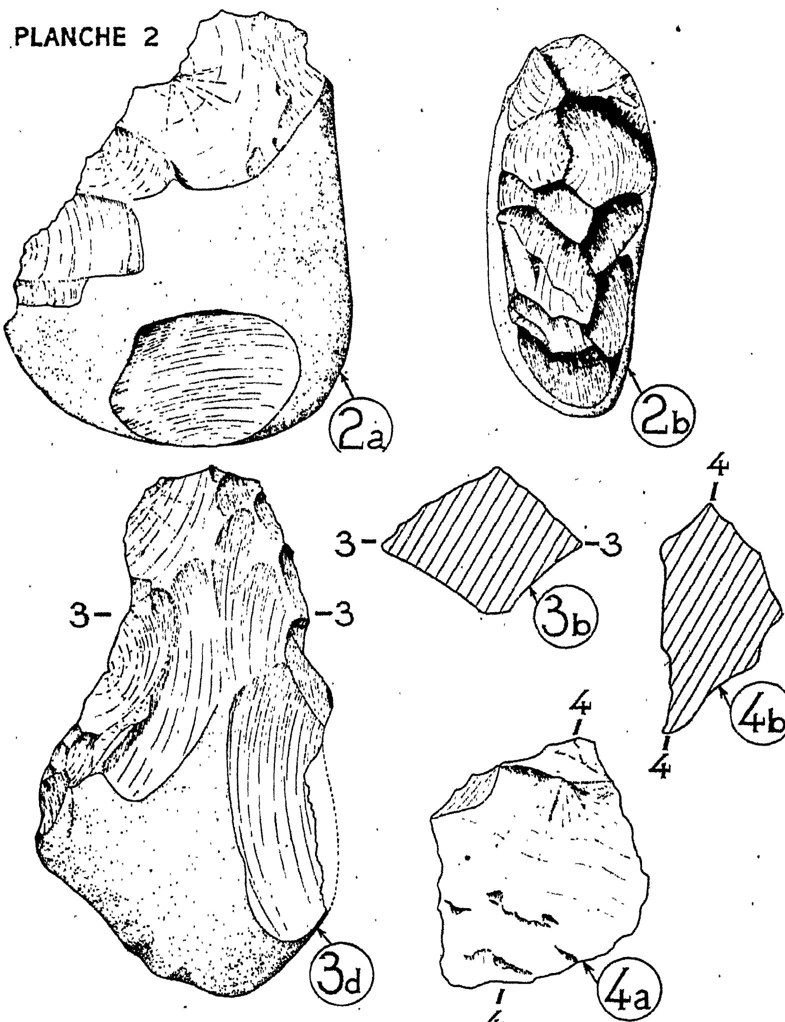
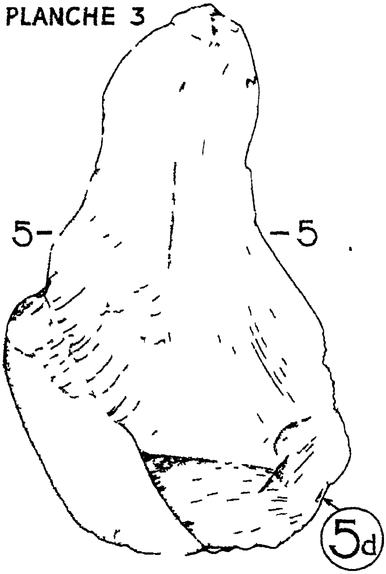
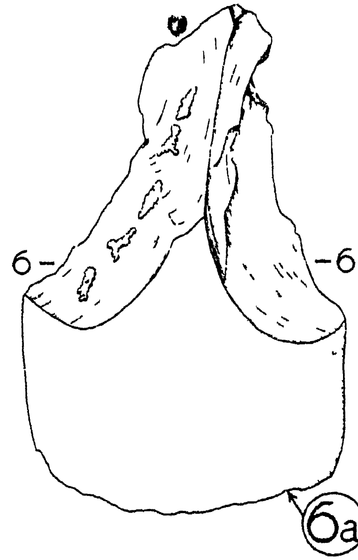
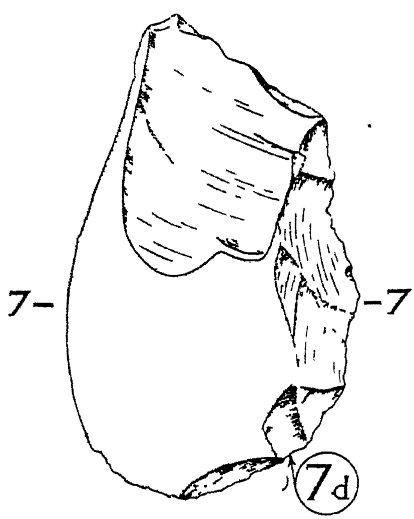


PLANCHE 3







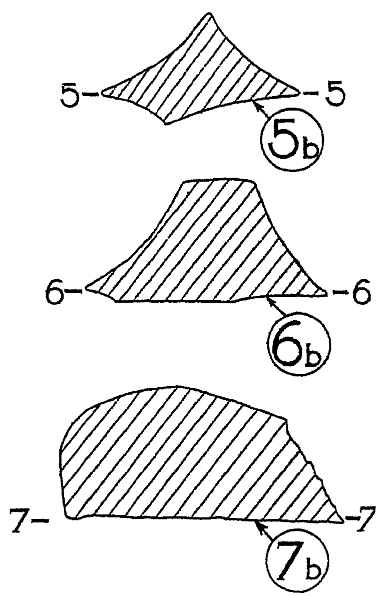


PLANCHE 4

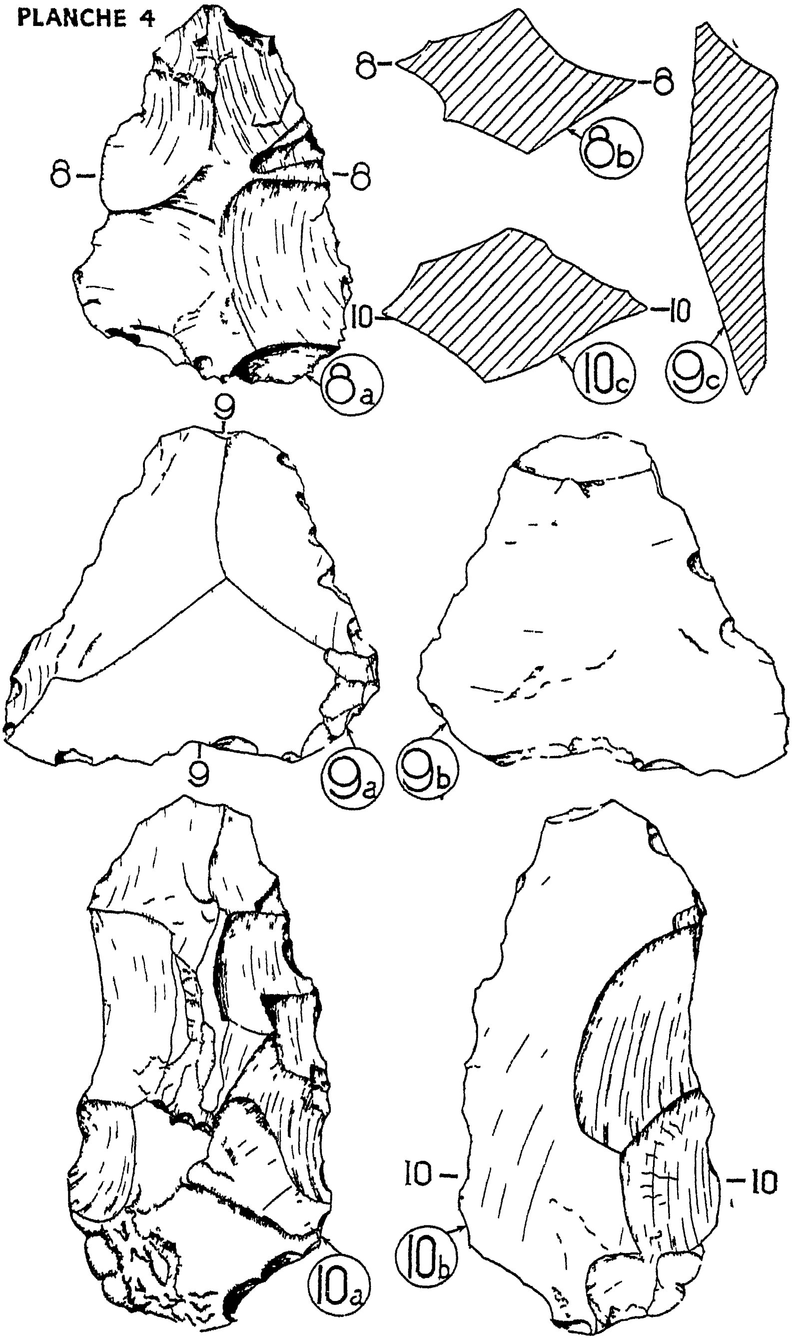
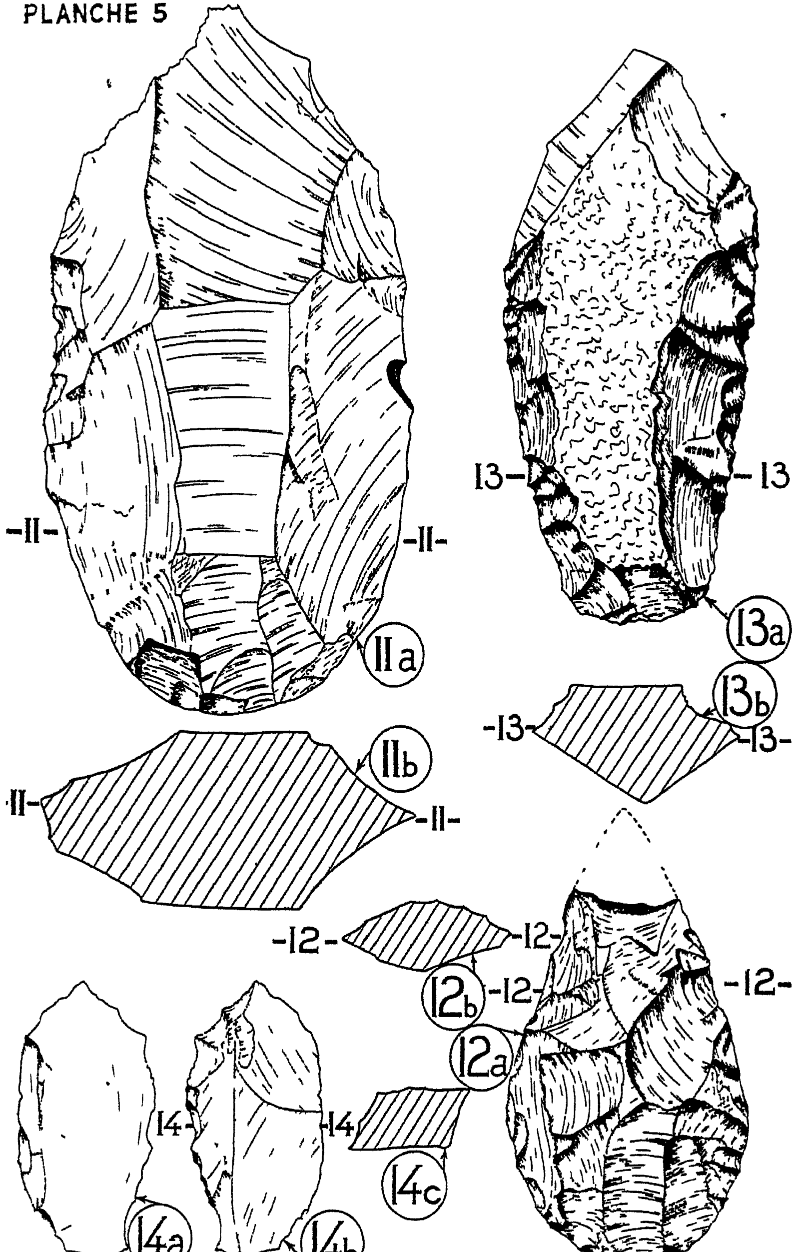


PLANCHE 5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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XLI, pp. 397-399, February, 1945.*

PSEUDO-IMPLEMENTS FROM THE GLACIAL CONGLOMERATES AT NOOITGEDACHT, DIST. KIMBERLEY

BY

HENRI BREUIL,

Archaeological Survey, Department of the Interior, Hon. Professor, University of the Witwatersrand.

With 3 Text Figures.

Read 3rd July, 1944.

I spoke to the South African Association for the Advancement of Science last year about quartzite pebbles trimmed by glacial action near Vereeniging (1943). I was anxious to avoid taking as elementary human work, natural fractures of chipped stones gathered in the ancient terraces of the Vaal, and I therefore wished to visit other wider exposures of the Dwyka Conglomerates from which they may have come.

During a visit to the McGregor Museum at Kimberley at the kind invitation of Miss Wilman, I had the luck, guided by Mr. Dold, to visit the glacial deposits of Dwyka partially masking the polished surfaces which are so striking at Nooitgedacht, as are the many beautiful prehistoric engravings which occur on them. I picked up a great many bruised and striated pebbles, of which a certain number, if the striations were not on the actual fractures, might easily pass as being elementary chipped stone tools. They are, by the way, not the same kind of stone as was employed by the Proto-Palaeolithic (Pre-Stellenbosch) people of the Vaal. Chert and agate were absent, lilonian quartz and indurated shale are very rare in the moraines, and not many show pseudo-trimming. Quartzite is very rare there too. The rock on which pseudo-trimming was produced is almost exclusively compact Ventersdorp Diabase, kindly identified for me by Mr. E. Mendelssohn of the Department of Geology in the University of the Witwatersrand. I, in duty bound, gave the McGregor Museum most of my harvest, except for a series for the collection at the Institute of Human Palaeontology in Paris and a few striking specimens for the Archaeological Survey here. My description is limited to the latter.

Figure 1· Pseudo hand-axe, more or less heartshaped, 13 cms long; width in the middle 9 cms.; thickness at the base 6 cms Globular base chipped round by three facets on the flat

reverse formed by a wide irregular cleavage. The upper face has the surface of the base and middle worn between a big flat facet with negative bulb on the left, from which some scaling on the edge passes over to the reverse. The right edge of the upper face has marginal scales or spalls struck off rather steeply.

Figure 2: Triangular flat pebble; the reverse, natural pebble surface, except for two small facets facing each other, one starting from the centre of an edge, the other from the angle. On the rather more convex upper face there is another short facet, halfway down the edge which was struck at the same time as the one mentioned above; the two other sides of the triangle show two wide flat facets, not very steep, made by mechanical fracture, the big one showing secondary flaking like re-trimming. Each of these fractures produced a concave cutting edge, the junction forming a sharp point. Size: following the axis of the point, 7·5 cms.; greatest width, 9·2 cms.; thickness of centre, 3·7 cms.

Figure 3: A flake struck off a pebble, the surface being the domed upper face and more or less vertical heel. The reverse shows the striking platform with bulb on the base, flat between two spindle-shaped reliefs; later mechanical action, also glacial. removed several flakes along the right edge and deeply notched (the heel) on the opposite edge; all the edges have been more or less bruised. Size: length 10 cms.; width 9·5 cms.; thickness of base, 4 cms. There are deep striations on the flake surface of this specimen.

This description of only three specimens is sufficient to show how necessary it is to examine the flaked pebbles very carefully, in regions which were covered by Carboniferous glaciers, if one is not to mistake these natural products for artificially shaped tools.

Since writing the above, Professor van Riet Lowe and I have recognised numerous pseudo-implements derived from Dwyka Conglomerates exposed near Bloemhof and Windsorton as well as on the Prime Minister's farm at Irene where scattered pebbles of quartz are all that now remain of the conglomerates that once extended over that area.

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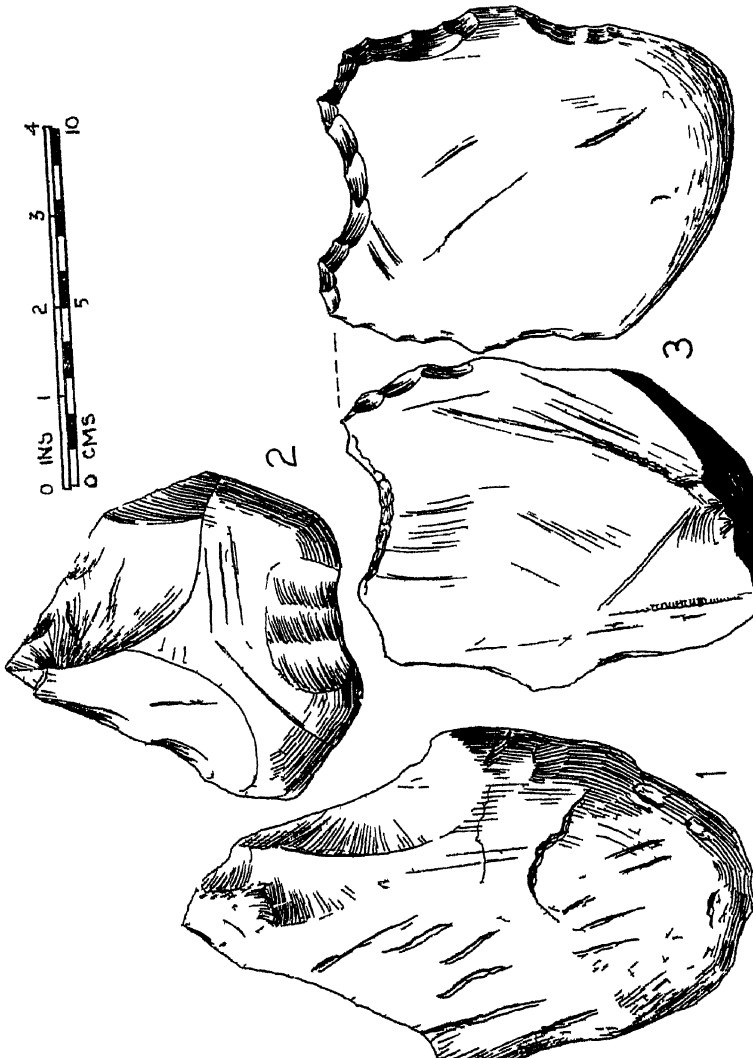
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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XLI, pp. 400-410, February, 1945.*

BIFACED MIDDLE STONE AGE POINTS FROM NATAL

BY

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Archaeological Survey, Johannesburg.

With 5 Text Figures.

Read 3rd July, 1944.

The object of this paper is to record certain finds which include bifaced lanceolate points from a number of sites in Natal. Most of these are the result of the devotion to our subject of Mr. J. A. Swan of Kimberley, who has for many years been an indefatigable collector and careful observer in the field of prehistory. His contributions both to the McGregor Museum at Kimberley and to the Museum of the Archæological Survey in Johannesburg are numerous and valuable, and have an added interest, since many of the sites are in remote areas difficult of access and seldom visited by archæologists.

I—REDHILLS, IZOTSHA

Twelve years ago, Chubb (1932) described and illustrated a solitary small triangular bifaced point presented to the Durban Museum by Mr. Swan, who found it at Redhills Farm, Izotsha. Last year Mr. Swan sent a further small collection from the same site to the Archæological Survey, so that it is now possible to add new information to Mr. Chubb's brief record. The site is described as being situated on Redhills Farm, owned by Mr. J. Voight, a short distance south-east of the Rev. Mr. Schultze's house and about two miles from the sea. The artifacts occur on the surface of red consolidated sand which is exposed under modern moving white sand dunes. Most of the specimens discovered in 1943 are of white porcelain-like chert stained a yellowish-red by the red sand A few pieces in silcrete are also present. Most of the specimens are fragmentary, but together with the waste flakes and blades show the very advanced Levallois technique employed in their production. The best pieces in this collection are illustrated in Fig. 1.

In addition to the specimens illustrated, the assemblage includes several points with plain flake surfaces and carefully prepared striking platforms, and side-scrapers with very fine Solutrean-like trimming.

In a donga which dissects the consolidated red sand, at depths of from 5 to 8 feet, Mr. Swan has found six handaxes

and a cleaver of Stellenbosch type. They are of quartzite, stained a deep red by the encasing deposit. The cleaver and two of the handaxes are on side flakes, while four handaxes are on cores. With the exception of the cleaver and one handaxe which show flat advanced Acheulean technique, the material is massive and crude, suggesting association with the lower or middle phases of the Stellenbosch cultures.

II—Granau, Izotsha

This site was discovered by Mr. Swan in 1943. It lies 1½ miles east of the Redhills site described above, on the farm Granau, owned by Mr. v. d. Ohe, and is half a mile from the sea. The horizon from which the artifacts come is exactly the same as at the previously known site, i.e., a windswept surface of consolidated red earth over which modern white sand dunes constantly move.

The material here is for the most part chert, though one beautiful point is on opaque, veined grey quartz (Fig. 2, 2). On this site the artifacts in chert have been leached out and completely altered so that the specimens are surprisingly light. They are matt white in colour and stained yellow; grains of sand adhering to them are red. The technique again is a very advanced Levallois, the debitage consisting of very slender blades, the striking platforms of which have been meticulously prepared by means of minute flaking. This collection does not differ in technique, typology, material or horizon from that found on the neighbouring Redhills site.

The most striking implements in this collection are illustrated in Fig. 2 and 3.

Specimens from Granau not illustrated include two less successful bifaced points, a crude unifaced point, a backed blade, a sidescraper similar to Fig. 3, 1, trimmed obliquely, a large plunging blade trimmed extensively on the upper face along both edges, and the tip of a small awl. The only core present is a very advanced flat oval Levallois core, 4·2 cm. x 3·3 cm., from which flakes of thumb-nail size have been struck radially; the under surface is that of a water-worn pebble, and is only slightly trimmed round the perimeter to provide striking platforms for flakes removed from the upper face. A score of waste blades, very thin for their length, with elaborately prepared butts, complete the collection. (In addition, there is a single later pebble tool in indurated shale typical of the late pebble industry of Natal described by Schofield (1936).

III—Golf Course, Umkomaas

During excavations for a new 11th tee on the golf course at Umkomaas in 1943, Mr. Swan recovered a perfect bifaced

point in brown quartzite (Fig. 4, 1). This was a solitary find, but obviously compares with the points from Granau described above (Fig. 2, 2 and 3). It is fresh and sharp. The butt is rounded, and the striking platform and bulb of percussion have been completely removed.

IV—Clansthal, Umkomaas

In a road cutting near Clansthal, at the Amahlongwana lagoon near Umkomaas, Mr. Swan found a beautiful bifaced point in cloudy quartz. It is trimmed completely over both faces by means of very thin flaking, but the striking platform is intact and was not facetted. It measures 4·4 cm. from point to butt, and has a maximum width of 2·9 cm. and maximum thickness of 1·0 cm. It is similar to the point from the Golf Course (Fig. 4, 1) in all important respects.

The horizon of this solitary find is comparable with that at Redhills and Granau, viz., a consolidated surface of red soil under 4 feet of moving white dunes. In red soil below this horizon, at depths of 10 to 15 feet, Mr. Swan discovered five handaxes of Stellenbosch type. Four of these are made of soft laminated shale which has hardly been indurated, material which possibly accounts for the extreme crudeness of the tools. The fifth is a simple handaxe on a water-worn pebble of harder indurated shale and has been water-worn since its manufacture.

At this site, therefore, we have the same stratification of very advanced Middle Stone Age material well separated from Stellenbosch implements at greater depth, as is found at Redhills, Izotsha, described above.

V—Eersteplan, Newcastle

A single beautiful bifaced point, although unassociated and of unknown horizon, should nevertheless be recorded (Fig. 5). It was found on the farm Eersteplan, Newcastle district, in 1937 by the owner, Mr. J. de Villiers Fourie. It was discovered at the edge of a stream after heavy rains, and may well have been derived from some higher horizon. Although the writer visited the site it was not possible to determine its horizon. This remarkable implement is of indurated shale weathered with a deep greyish crust. Its maximum measurements are: Length, 14·4 cm.; width, 4·7 cm.; thickness, 1·6 cm. It is clearly made on a long, slender blade, as is shown by the slight longitudinal curve of the implement and the asymmetrically biconvex cross-section. Since both surfaces are completely covered by Solutrean-like secondary trimming flakes, and as the butt is missing, it is not possible to determine absolutely the technique by which the flake was originally prepared, but there can be little doubt that it was obtained in the Levallois manner. Unfortunately both the point and the striking platform are missing, the fractured

surfaces being weathered to the same grey incrustation as the rest of the implement.

VI—Tugela Mouth

This site has been fully described by Brien in two papers (1935 and 1937), who drew attention to the occurrence there of bifaced points of Middle Stone Age type in apparent association with Stellenbosch handaxes and flakes with Levallois characteristics. A collection from the same site presented to the Archaeological Survey contains this same association, and two of the bifaced points in the Survey collection are illustrated in Fig. 4, 2 and 3. They are accompanied by typical Levallois flakes and cores, though the latter are commonly on water-worn pebbles which retain a considerable amount of the original cortex. Although it is true, as Mr. Cramb points out, that, with the exception of bifaced points, the more complicated tools commonly associated with the Middle Stone Age are absent, we cannot agree with Mr. Cramb's tentative conclusion that the bifaced points and Levallois elements are to be associated with the handaxes found on the same site. Had the handaxes been more reminiscent of Fauresmith types one would be more ready to accept the view that the site represents one homogeneous industry. My own opinion, based purely on the collection available to me, is that it is a mixture of Early and Middle Stone Age industries, the simplicity of the latter being probably accounted for by the material used—quartzite, which elsewhere, as, for instance, in the Mossel Bay industry, also results in the minimum of secondary retouch, and a general simplicity of tool types.

VII—Other Sites

To complete the known distribution of bifaced Middle Stone Age points in Natal we must note those described by Brien (1932 and 1935) from Durban North, Greenwood Park, Umhloti and Karridene.

Discussion

It has been shown that Middle Stone Age industries containing lanceolate bifaced points have a wide distribution throughout Natal. These have generally been ascribed to the Still Bay culture, though it is interesting to note that Chubb said of the original point from Izotsha: "Its technique seems superior to the best Solutrean-like implements that have been obtained in South Africa." This is supported by the new material from the two sites at Izotsha. The bifaced points certainly remind one of the Still Bay, but the other tools, and particularly the débitage, suggest something rather more advanced, and recall the Modderpoort culture (Malan, 1942).

Because the Still Bay culture of the Cape was the first containing bifaced points to be described, it naturally became the basis for comparison with industries containing bifaced

points subsequently found elsewhere. It does not seem to follow, however, that all such industries are necessarily to be ascribed to the Still Bay culture. There is a marked tendency, not only in the Union but also far beyond its boundaries, to ascribe all industries which include bifaced points to the Still Bay. While this may yet prove to be justified, it would be prudent at the present stage of our knowledge to keep a more open mind, and to remember that the Still Bay culture *(sensu stricto)* is essentially a product of the silcrete areas of the Cape littoral. The very fact that the bifaced point is found so widely distributed in and beyond the Union makes that tool type dangerous to use as a basis for identifying industries containing it.

Is it not possible that different groups of people within the Middle Stone Age might have developed the bifaced point in the course of the evolution of the Levallois technique, and that this tool type may have arisen independently in different areas? If this is so, the bifaced point may mark the arrival, not necessarily at the same time, of different industries at approximately the same stage of technical development. On the other hand, if it be held that so specialised a tool type must imply underlying cultural affinities between all industries which contain it, room must be left for the possibility that the true centre of its development and dispersion may not be the southernmost extremity of its occurrence, but might lie in any of the more northern areas which have yielded this tool.

It should also be remembered that identical tool types may be the results of very different technical processes. These technical processes are best studied by examination of the cores, waste flakes and other débitage, and are often not adequately reflected in the completed tool, especially when it is covered by extensive secondary work, as in the case of bifaced points. While the Levallois technique is common to all South African Middle Stone Age industries, there exist variations in its application and development which are significant. While comparison of the bifaced points suggests some degree of identity between the industries described from Natal and the Still Bay of the Cape, a study of the associated débitage brings out differences which challenge such a conclusion.

These suggestions are, of course, merely tentative, but serve to indicate that definite conclusions should be avoided at this stage. Our eventual aim must naturally be synthesis and correlation, but premature identification of widely separated industries can only hamper our arrival at a true interpretation of real cultural relationships.

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INDEX TO ILLUSTRATIONS.

Figure 1: Redhills, Izotsha. (Half natural scale).

1. Fragment of point, partially trimmed on flake surface Silcrete.
2. Thick triangular point, steeply trimmed on one face only. Chert.
3. Fragment of point, finely trimmed on one face only. Chert.
4. Backed blade, fragmentary, trimmed along portion of arc. Chert.
5. Backed blade, fragmentary, trimmed along whole of arc. Chert.

Figure 2: Granau, Izotsha. (Half natural scale.) (See text.).

Figure 3: Granau, Izotsha. (Half natural scale.)

1. Oblique scraper on Levallois flake, coarse-grained surface quarzite.
2. Backed blade on Levallois flake, trimmed along whole of arc. Chert.
3. Levallois flake, small length of one edge steeply trimmed. Chert.
4. Thick, well-trimmed point, bulb of percussion removed extensively. Chert.

Figure 4. (Half natural scale.)

1. Golf Course, Umkomaas. Bifaced point. Quartzite. (Maximum thickness, 0·8 cm.)

2 and 3. Red Hill, Tugela Mouth.

2. Bifaced point, fragmentary, quartzitic sandstone.
3. Bifaced point, striking platform slightly faceted. Cloudy quartz.

Figure 5: Kersteplan, Newcastle. (Natural scale.)

Long, thin bifaced point; indurated shale.

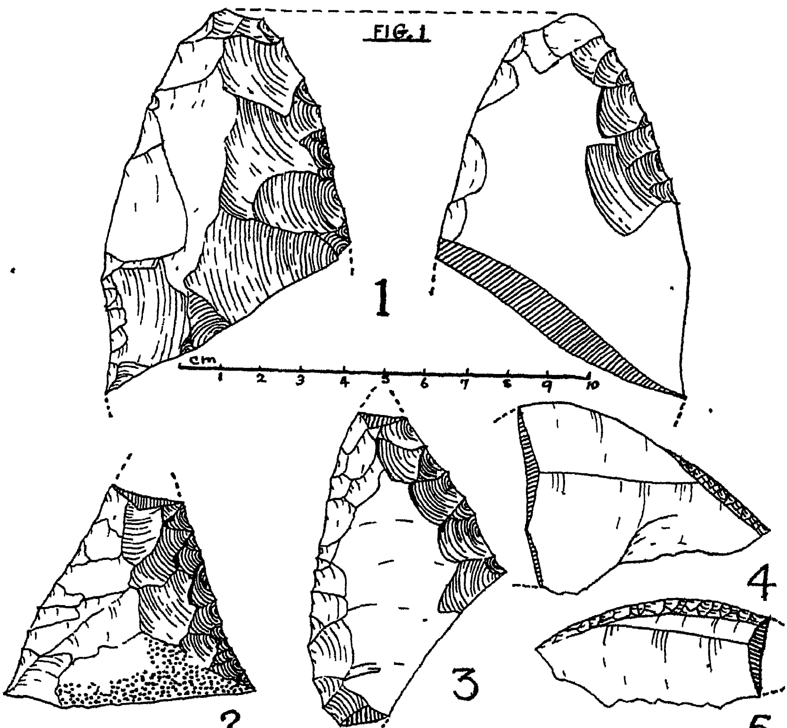
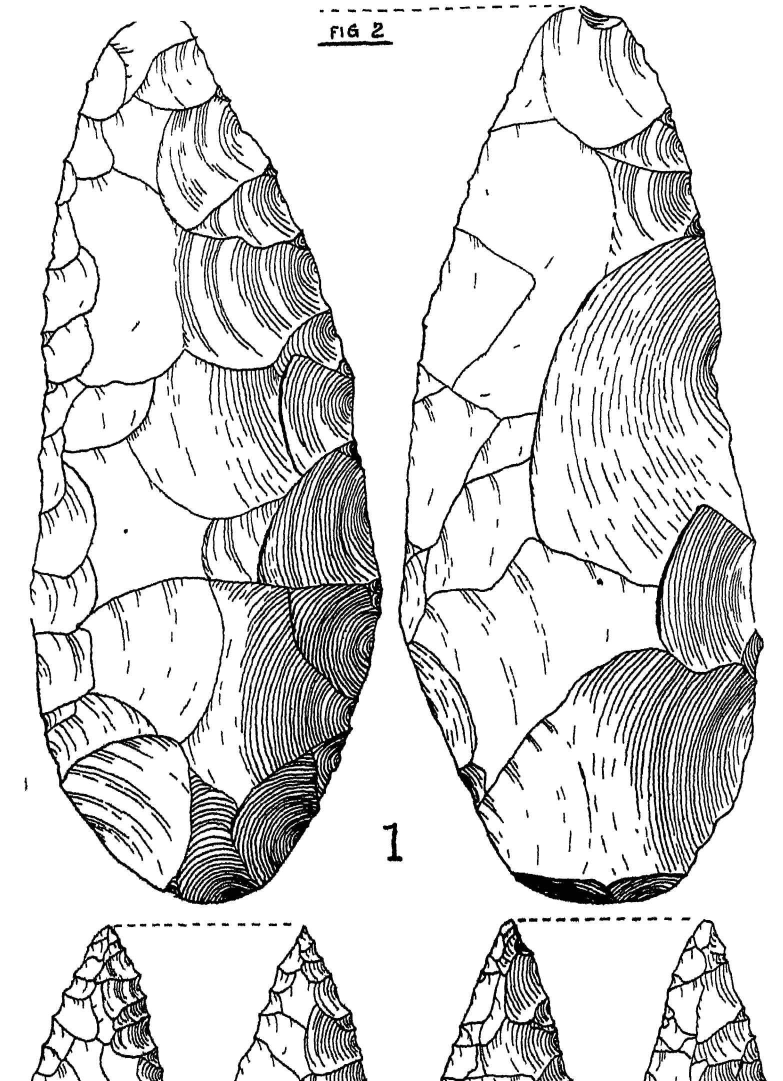


FIG. 1
1
cm
1 2 3 4 5 6 7 8 9 10
2
3
4
5

FIG 2



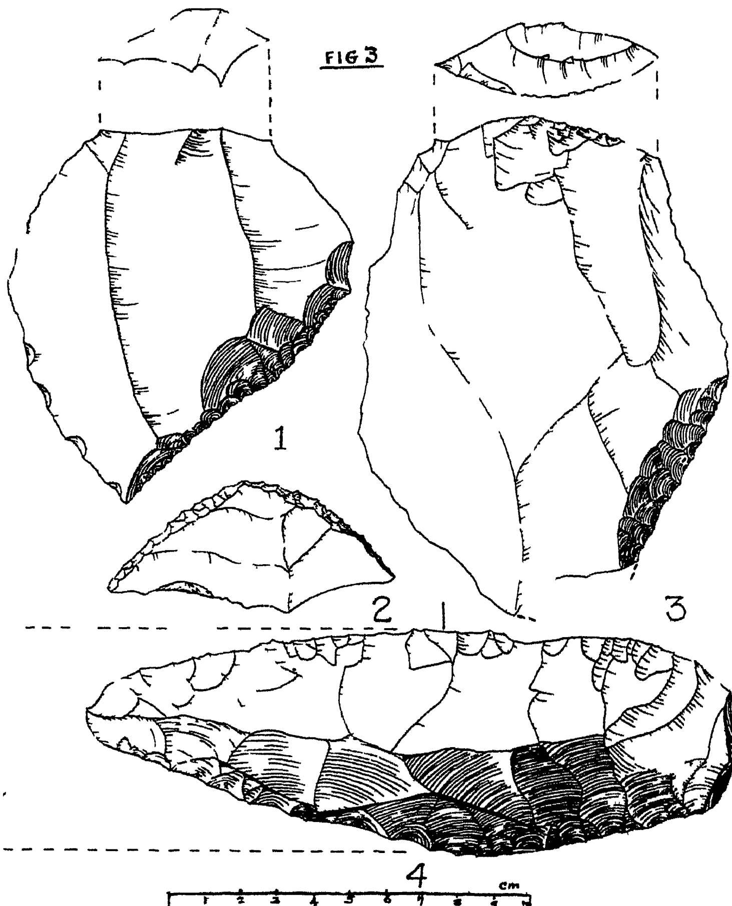
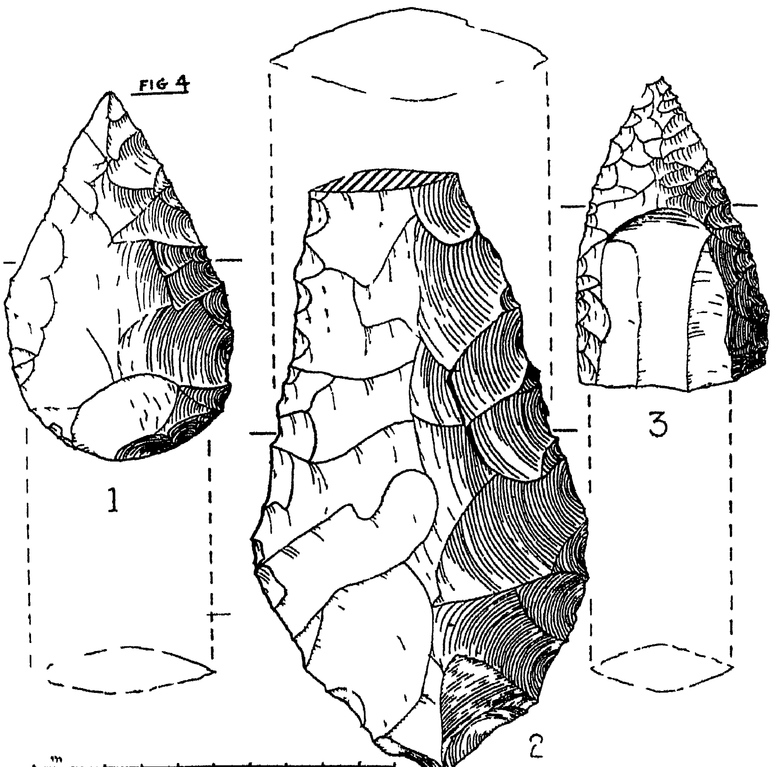


FIG 3
1
2
3
4
cm
1 2 3 4 5 6 7 8 9 10

FIG 4



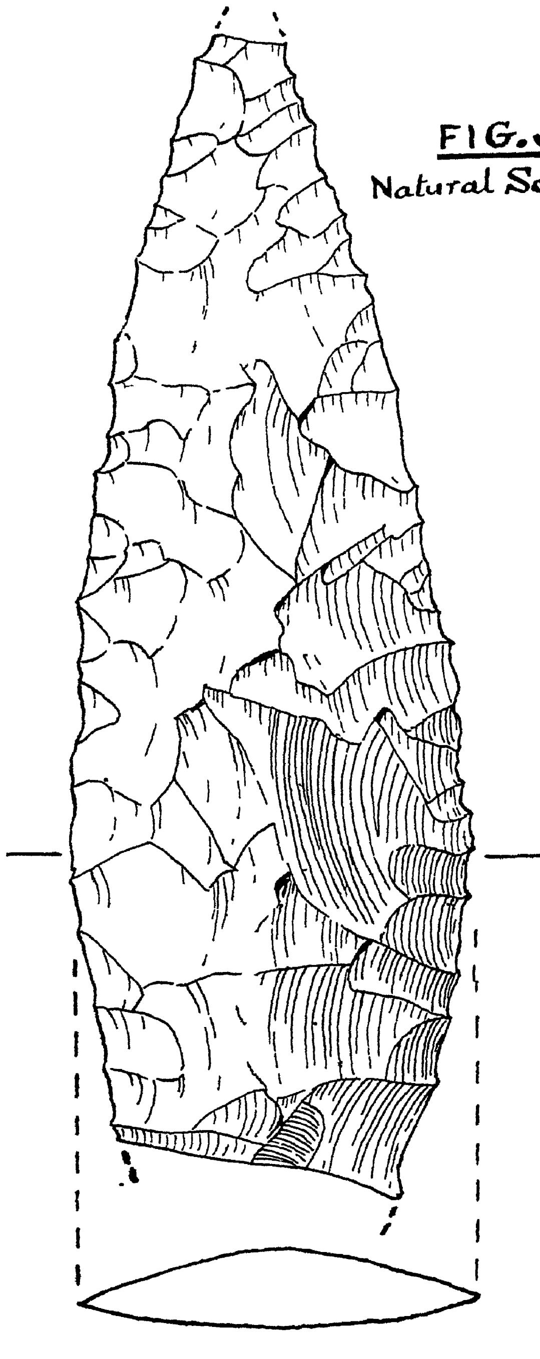


FIG. 5.
Natural Scale

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February, 1945

EDGED DISKS AND ARMRINGS

BY

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With 3 Text Figures.

Read 3rd July, 1944.

At the request of Mr. Goodwin, author of an article with the above title in this Journal (Vol. XL, pp. 296-302, 1943), the following notes are given as a necessary supplement to his paper. When writing his article it had escaped his memory that he must have seen " an unbored stone-lens " and a stone-bowl during one of his visits to my collection.

About twenty years ago the specimens were presented to me as " coming from a young man living along the Orange River in Gordonia." Our literature of those early days had made no mention of the like and I looked upon them as mere curios; possibly the work of Afrikaner Voortrekkers, particularly the stone-bowl that might well have served as a pan or dish, replacing crockery. There are no data at our disposal for associating the two artefacts.

Description.

Fig. 1 shows the bowl, measuring externally 20 by 17 by 5·6 cm.; internally 15·8 by 13·2 by 3 cm. The interior oval is more perfect than the outside, the latter having received far less attention in shaping than the other. Parts of the irregular rim and bottom show marks of pecking. The material, a micaceous gneiss, is fairly soft and therefore more easily hollowed out without cracking. The work is here more rough and ready, a suitable pebble having been selected and by the pecking method reduced to a shape that " would do."

Fig. 2. The lens measures 10·6 cm. in diameter and 4·5 cm. in thickness; the surfaces are perfectly bi-convex, the arc of curvature being that of a circle with a radius of 8 cm. The edge is blunted, probably through subsequent usage as a hammering stone or as an edged anvil. The uniformity of the perimeter and the bulging surfaces show a high degree of

workmanship. Its material, granite, allowed of a finer final polish than the gneiss specimen.

Fig 3. From the collection of Rev. Breedt, Wellington, I possess a disk, perforated and edged. It bears traces of having first been shaped by pecking; then bored; and finally ground down so that the surfaces meet in a circular boundary or edge. On each side the grinding proceeds from the bore towards the rim; the remains of four facets, so produced on opposite sides to the hole, can still be made out. The hard grinding stone was apparently flat or only slightly concave. The boundaries of the facets were then finally pared down with a stone file. Dimensions: Diameter 7·7 cm., bore 3·3 and 1·5 cm., height 3·3 and 3·1 cm.

The borehole is not finished in the usual hourglass fashion but shows some ridges as seen in Fig. 3 (b). These were not due to any flaw in the material, the ordinary greenstone. Mr. Goodwin has found a similar ridge in a specimen from Storms River (Knysna) and inclines to the view that it was a dagga-pipe bowl. If this applies to my specimen, we are dealing with a contrivance of fairly recent date, when an ordinary !Qué or disk was adapted to a new use, an edge being required instead of the broad curvature of the !Qué. The edge in Fig. 3 differs from that of the lens, Fig. 2, in being plain and unused.

How ancient man could produce a lens shown in Fig. 2 long before applied mechanics had established the laws of the process and the machinery for this purpose, naturally perplexes the student. Mr. Goodwin, while referring to the modern technique for convex lenses of glass, does so without prejudice. The modern method applies rotatory motion for grinding, while for the final polishing the hand takes a more active part. Fifty years ago, when emery paper was still scarce, we used sand on a piece of soft leather placed into the palm of the hand for rounding the top of our stick. The solution of the riddle lies perhaps in this direction.

The marks of striation left by rotatory grinding must run parallel to the rim, and will be concentric. This fact is shown in a symmetrical polished !Qué (14·8 cm. wide, 10 cm. high) which I dug up at Blouputs (Britstown) from a layer containing "tanged" arrowheads, the same material which later on at Hopetown, yielded also a fragmentary edged ring; both sites on river banks, not at a fountain. This !Qué had in succession undergone the processes: pecking to shape, boring, rotatory grinding, filing, polishing. A concave "mortar," at least 15 cm wide and 5 cm. deep, had, as usual, not been left on the site. Nor did I ever come across a rock showing such concavity.

In the Cape Province the striation marks on ground and polished artefacts—armrings included—run at an angle to the edge, are mostly straight and in sets parallel to each other; the direction may vary. To this I had drawn attention in my first article on "Ground and Polished Stone Implements"; but the JOURNAL OF SCIENCE, XXIII, 1926, published it only in abstract form. Since then I could exhibit the ring fragment from Hopetown with the like striations. Such marks can be left on the artefact (a) by rubbing it on the grinding-stone, or (b) by moving the grinder, rasp or file over it. In (a) it moved to and fro, horizontally, in (b) the direction changed as required. In 1926 several stone-files belonging to Rev. Breedt's collection were exhibited.

In 1933 I too believed that the "lens" formed the basis for the edged ring. Closer study of the lens in Fig 2 has convinced me that only the rim of a disk, of certain width, thickness and shape, was required; isoscelene in section. A flat slab was reduced to a circular flat disk, (a) by pecking (as instanced by an unfinished ring from Natal), and or (b) by grinding (as shown in a neolithic whorl from Europe, and a fragmentary slab from Knysna in my collection). The perimeter was then bevelled all round it to the desired width on the ring, broader above than below. The bevels meet in a circular edge, running at a level, nearer to the lower surface (specimen Platbosch). The flat central part of the solid disk was then removed by boring the hole and enlarging it by means of a conical "reamer" until the bevels were reached, the flat

surface preventing wobbling, thus ensuring success. In the case of the smaller and thinner rings wide mortars may have acted as supports, while the conical pestles (wood or stone) were used as reamers. The ordinary grinding stone, slightly hollowed, would have yielded the proper bevel to the solid disk.

Conclusion.

The South African ring-disks bear a striking resemblance with the "anneaux-disques" that made their first appearance in Europe, North Africa, the Near and Far East during the beginning of the Neolithic Period. In the Mannus-Bibliothek No. 10 Dr. G. Wilke published, in 1923, a most instructive and well documented essay on "Cultural Relations between India, the Orient and Europe." Our rings did not appear; nor has to my knowledge South Africa produced fragmentary rings, that were re-bored for serving as pendants.

Note.—For "Britstown Culture," the transitional stage between Palaeo- and Neolithic material in South Africa, cf. Heese: "Evolution of Pal. Technique, *Annals Univ. Stell.* XI. B, No. 2, pp. 59-63 (1933).

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THE ORANGE RIVER HIGH LEVEL GRAVELS AT ALIWAL NORTH IN RELATION TO CRUSTAL MOVEMENT AND THE STONE AGE

BY

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With 1 Map and 35 Text Figures.

Read 4th July, 1944

When passing through Aliwal North in June, 1942, some high level gravel beds were noticed by the writer on the right bank of the Orange River above the General Hertzog Bridge; an examination of the gravels proved that they contained stone implements, but for lack of time the matter was left in abeyance until June, 1943.

Aliwal North has long been known for its archaeological and paleontological remains. It was the home of the late Alfred Brown, one of South Africa's first investigators in these fields; whose life story is the subject of a charming and whimsical biography by Prof. M. R. Drennan. Brown apparently confined himself to the collection of Middle Stone Age and Smithfield types of implements (Goodwin and Van Riet Lowe, 1928); strangely enough he neglected the river gravels in his search for specimens, otherwise implements of a Stellenbosch type would certainly have found their way into his collection.

Prof. Van Riet Lowe has recorded implements of Smithfield type from the area (Goodwin and Van Riet Lowe, 1928), while Prof. M. R. Drennan, during his residence in Aliwal North, collected a large number of implements of late Fauresmith, M.S.A. Smithfield types, some of which were from the river gravels, but unfortunately they have not been recorded. Prof. Wellington has described the middle course of the Orange, but as far as the writer knows, no physiographical description of the Upper Orange has yet appeared.

The field of investigation covered in this paper is outlined in the accompanying sketch-map of the area, showing about 10 miles of the Orange and Kraai Rivers from the poort near the Kraai bridge to the poort near Maizefield and for three miles up the Orange from its junction with the Kraai.

The High Level Gravels.

These gravels are water-worn aggraded river deposits, varying in depth from 4 feet to 40 feet at their deepest exposures; they are of two types:—

(a) heavy pebble in a loose sandy matrix, fairly consolidated when lime is present, and roughly stratified, the groundmass being made up of quartzites, agate, shale and lavas derived from the Drakensberg Volcanics;

(b) the other type is a loose current-bedded grit, usually of much greater depth than the pebble type and appears to demarcate the banks of the former stream. The grits contain few implements when compared with the relative richness of the heavy gravel, but both types appear to be diamantiferous; test holes put down in search of the gems have helped investigation considerably.

By reference to the map it will be seen that the gravels rise from a point on the Kraai River 40 feet above its bed, follow a tilted scarp to a height of 120 feet, step up to 150 feet, fall away to 80 feet on the left bank of the Orange, appearing again on the right bank at a height of 220 feet to fall away towards the 40 feet silt terrace on the Orange and in the direction of Kleinpoortje Spruit, where the gravels are again exposed.

The Orange and not the Kraai is presumed to have deposited the gravel now lining the left bank of the Kraai; this is indicated by the following observations:—

1. The absence of gravels on the right bank of the Orange for some miles above the General Hertzog Bridge and on the left bank just above the junction with the Kraai.
2. The similarity of the gravels on the Kraai to those on the right bank of the Orange.
3. The diamantiferous nature of the gravels. No diamonds have as yet been reported from higher up the Kraai River.
4. Topographical considerations show that it was possible for the Orange to have taken a course as indicated on the map.

The gravel run now assumes the form of a cut-off meander, bisected in turn by the Kraai near Botha's Dam and by the Orange near the General Hertzog Bridge.

The topographic aspect of the gravel runs is somewhat similar to those described on the Kornet Spruit (Macfarlane, 1942). These are little koppies-like formations jutting out in a series of small bluffs. A well-defined terrace is evident on a part of the Kraai bank, while incipient terracing may be conjectured on the right bank of the Orange below the General Hertzog Bridge, but the writer does not view those terraces as having been cut by that river. Later silts form a 40ft. terrace on the right bank of the Orange above and below the bridge and a 30ft. terrace on the banks of the Kraai, but these silts reach up to a height of 80 feet on the Kraai and form banks 100 feet in depth on the left bank of the Orange. There is also evidence of former fingering to a height of 150 feet above the bridge, so it would appear that, whatever terracing there has been, it was actually done after the silts were deposited, the silts having been planed by flood water.

Interpretation of the silt and gravel runs:—

Age.—With the exception of an isolated and shallow bed at G on the section G—H, 300 feet above the Orange River (which contains implements of an indefinite form), implements of a Levallois type were recovered in every exposure examined. This would date the gravel as being of approximately Upper Pleistocene Age.

River Erosion and the Carving of the present Valley.—During the deposition of the high level gravel runs the Orange was a mature aggrading stream with the possibility of having attained grade. It then apparently changed its habit and began to degrade, cutting down 220 feet from the Upper Pleistocene to the present; depositing its gravel load as it did so, but strangely at random and very capriciously, if the whole of the valley in the Aliwal area has been carved by the river. Apart from the gravel runs indicated on the map, large areas between the 40ft. and 220ft. contours show no evidence of fluviatile deposits or of river erosion. That the Orange became rejuvenated is obvious, but how it was possible for it to become a degrading stream and a river of silt aggradation at the same time is not apparent. If it is assumed that the silts were deposited after the valley had been carved into its present form there is still the factor of uneven distribution. If a climatic change is postulated, and if the lowest exposure of the gravel on the Kraai River is accepted as the datum, there is the serious difficulty of trying to reconcile a degrading river which has cut through the strata to a depth of nearly 200 feet during the Fauresmith period, but no more than 40 feet since then. Apart from the above difficulties the most serious objection to river erosion is furnished by the presumed fault-scarp flanking the left bank of the Kraai River (see profile C—D), which clearly indicates an upstream tilting after the deposition of the overlying gravels.

Left Bank of Kraai and Upstream Tilting.—The fault-scarp is of reddish Beaufort mudstone capped by a sheet of standstone 4 feet to 8 feet in thickness and overlain by a heavy gravel bed 6 feet to 12 feet in depth. The scarp rises from the 30ft. silt terrace to a height of 120 feet and takes a rather sinuous north-westerly trend for a quarter of a mile; it sweeps round in a sharp right-angled bend to the west for about half the distance, while the sandstone dips upstream at an angle of two degrees in its northerly trend and shows, a slight inclination of strike to the west in rounding the bend with slight sagging and disruption at one point; there is evidence of drag at both extremities of the scarp where it makes contact with dolerite. (See Sections D'—E', E—F and profile C—D.)

It is fairly steep in its northerly and almost vertical in its westerly trend, with a remarkably fresh appearance, and has suffered little dissection apart from the erosion of the overlying gravel. A small residual rises from the terrace at the foot of the

scarp and the inclination of the sandstone capping the residual conforms to that of the scarp and is also overlain by river gravel of the same age.

Above the scarp is a terrace-like platform of gravel resting on the tilted sandstone; from this platform the gravel steps up in a 30—40ft. scarp, also trending north-west; the scarp fades into the platform to the south-east into a slightly depressed area to the north-west; bending is apparent along the crest of the scarp. These two scarps are interpreted as normal fault scarps; the Aliwal hot springs are apparently on this line of faulting.

An area of slight depression divides the gravel as it swings round the bend of the Kraai, the gravel emerging again in a characteristic scarp with koppie-like bluffs flanking a lower dolerite ridge. This ridge divides the river from the scarp, which appears to have been uplifted and to be a continuation of the lower scarp of the Kraai; the scarp has an arcuate east to west trend, the shape apparently being controlled by the dolerite ridge into which it appears to fade out. A dolerite sill on this arc between the two scarps appears to show a certain amount of fresh disruption along its scarp.

There is a very good exposure of the old river bed in a road quarry near the scarp (see Section B—C). The gravel shows clearly the aggrading nature of the former stream, being heavy and ill-sorted, with fair stratification to a depth of 10 feet; the major axes of the pebbles indicate a flow at right angles to the scarp, but the exposure on the extreme left face of the quarry indicates a later flow parallel to the scarp. At this point the surface of the gravel bed has a peculiar short undulation at right angles to the scarp, forming an ogee curve, the section along the arch of which has been exposed in the quarry. No apparent bending of the gravel bed was noticed; the inverted curve may have been cut by the river, but the trough is very short and not conclusive; surface indications suggest that the gravel underlies much of the golf course area.

Right Bank of the Orange and Down-stream Tilting.—The highest exposure of the gravel on the right of the Orange occurs above the General Hertzog Bridge at a height of 220 feet above the present river bed (see Section A—B). The gravel runs, which correspond to those on the left bank of the Orange and Kraai Rivers, descend in mound-like steps somewhat diagonally to the 40ft. silt terrace below the bridge and appear to underlie it. Further runs of the gravel can be traced along the gently-declining bank towards Kleinpoortjie and the poort on the Orange. Good exposures have been made in the gravel by quarry men, diamond prospectors and railway labourers. The exposure of gravel in a 10ft. quarry 220 feet above the Hertzog Bridge reveals a loose heavy gravel of well-rounded pebbles varying from an inch to six inches. One portion of the pit contains a calcareous pocket, the gravel being overlain in parts by reddish river sands 2 feet deep. Other exposures of the gravel occur at various heights down to the

40ft. silt terrace, the gravel becoming lighter below 80 feet. Mr. de Wet, the owner of the farm "Kleinpoortjie," informed me that there was an exposure of the heavy gravel in the face of the 40ft. terrace bordering the river, but this I was unable to verify.

About three miles below the General Hertzog Bridge the Orange breaks through a hilly ridge; if a level be taken from the 220ft. quarry to the ridge a well-defined bench is seen with a slight dip inwards to the river from both banks; the bench is particularly well defined at Kleinpoortjie, where the sandstone scarp of the bench appears to indicate shattering along its line; the bench and scarp merge into the hillside to the west. If this bench with scarp represents a faulting of the old river peneplane it becomes possible to postulate down-stream tilting of the old river bed, and the peculiar arching of the gravel runs between the poorts on the Kraai and Orange (map A—D) becomes better understood. In plotting the gravel runs between these two points a well-defined arching of the former river bed is at once apparent; it is abnormal if viewed as a single uplift in the confined area of the Aliwal Valley, but is not extraordinary if faulting had occurred across the Orange at the poort. The bisection of the old bed by the present river is possibly due to a rift or fault parallel to the stream. A tentative fault diagram has been prepared to illustrate the possible movements.

It would appear that the whole area under review has been subjected to uplift, which has been accompanied by faulting and subsequent adjustments, just as on the Kornet Spruit, a sandstone block some miles in length and of considerable thickness has become down-tilted into the river bed, the block fracturing at several points across its length. The point of the block now lies athwart the Kornet Spruit and forms a small island when the river is in flood. The top of the block stands 90 feet above the river bed; in its present position it is below an adjacent deposit of high-level gravels, so the river must have passed over it.

Bending of the crust from north to south would appear to be indicated by the raising of the old river bed at the Kornet Spruit to 120 feet above the present river (Macfarlane, 1942), and by the raising of the old Orange River bed at Aliwal North to a height of 220 feet—300 feet if the gravel on the left bank above the waterworks (map section H—G) proves to be of the same age Strikingly, the rise of the gravels above the present river beds becomes *greater* as the gravels recede from the mountain mass in Basutoland. Dr. du Toit had dealt elsewhere with this relative rise of the lighter crust in relation to the main mountain mass in the Karoo-Basutoland Basin, together with the related crustal movements in the adjacent areas (du Toit, 1931). In dealing with the Orange River Dr. du Toit postulates that the Orange retained its course with the elevation of the land and cites the breach of the Buchuberg in support of it. This slow elevation of the land appears to be at variance with the phenomena observed by the writer on the Caledon at Maseru, Little Caledon,

Kornet Spruit, the Orange River at Aliwal North and the East London area where the evidence suggests that the movements were sudden and of a diastrophic nature.

Nevertheless, such apparent uplift athwart the old river beds of the Caledon, Little Caledon, Kornet and Orange Rivers suggests an axis remarkably parallel to Dr. du Toit's Griqualand-Transvaal axis; if the area extending from Maseru to Vereeniging proves to have been elevated during the same period it would add to this parallel. Further correlation is suggested if the Vaal River below Vereeniging is flowing in a down-warp and the divides separating the Vaal-Caledon and the Caledon-Kornet Spruit are proved to be axes of uplift, with the Upper Orange breaking across these axes. The writer is only concerned with geological phenomena in its relation to Man's past, and how far Pleistocene movements can be correlated with earlier crustal movements must be left to those who are more fitted for the task. The Pleistocene movements appear to the writer to be much greater than the minor adjustments postulated by Dr. du Toit, as following the Tertiary movements, there is the possibility of the main movement having really taken place during the Upper-Pleistocene.

Visser, Sohnge and Van Riet Lowe (1937) have dealt fully with the geology and archaeology of the Vaal River Basin, but have recognised no movements of a tectonic nature during the Pleistocene in that area. This view appears to have been modified by Prof. Breuil (1943), who considers that the old red quartzitic Stellenbosch I gravels on a 50ft. terrace of the Klip River near its junction with the Vaal are earlier than the tectonic phenomena postulated by Dr. du Toit (1933). In a further contribution (this Journal, 1943), implements of a pre-Stellenbosch type were collected by him from the old gravels at heights of 60 feet to 80 feet, 150 feet and at 200 feet above the Vaal in the Windsorton-Barkly West area. Implements of a later date are also apparently contained in these gravels; these later implements are presumed to have been "introduced into the gravels by nature or by man." The part played by nature in the deposition of the implements in the gravels is an open question, but that they were introduced by man is rather difficult to accept in the light of the evidence from the Orange and Kornet Spruit high-level gravels.

Past Climates.—No evidence in support of changes in climate during the Pleistocene is apparent in the river deposits studied in the Aliwal North area. The reddish nature of the sand in the gravel, and overlying it in places, is probably due to the prevailing reddish mudstone and shale of the basin.

Lime is widely distributed in the gravel, and in places below the gravel, so it would appear that the cementation by lime has progressed through the Pleistocene to the present.

The high banks of silts as distinct from the present river alluvium are probably due to the ponding back of the Orange

through uplift and disruption. This in turn was followed by the rejuvenation of the Orange.

The indications would suggest the flow of the Orange during the Upper Pleistocene to have been greater than now, but river capture may have been an important factor here. Dr. L. C. King, in a letter to Dr. du Toit, has deduced the capture of one of the head tributaries of the Orange by the Tugela. It would thus appear to the writer that, until the geomorphological background of the Pleistocene is better understood, no useful purpose can be served by postulating changes of climate during the Pleistocene in the Upper Orange River basin.

The only fossil evidence collected from the Orange River gravel at Aliwal North is a small fragment of a tooth, probably of equine origin. Mr. de Wet, of Kleinpoortjie, informed me that many fossils were found when the gravels were worked for diamonds, but all have apparently been lost.

ARCHAEOLOGICAL.

The high-level gravels, from 40 feet above the Kraai River bed near Botha's Dam to the 200ft. exposure on the right bank of the Orange above the General Hertzog bridge and down to the 40ft. silt terrace, have all yielded implements of waterborne nature; some are so heavily rolled that they have almost lost their identity, but a few found in situ during excavation are unrolled. The only stratigraphy apparent in the gravels is that the later Fauresmith appears to represent the last phase of river aggradation, but apart from this no separation of the cultural types as represented by the Pre-Stellenbosch, Stellenbosch and Fauresmith I was found possible. The rather fresh-looking, unabraded M.S.A. types do occur in surface accumulations of soil and also on the surface, so it is perhaps safer to assume that those implements were made subsequently to the movements outlined in this paper, but the evidence is not conclusive. It appears certain that some of the pebbles from the gravel and also some of the rolled implements were fashioned and reflaked by Smithfield Man after the gravels had assumed their present topographical aspect. The silts lining the banks of the consequent stream of the Kleinpoortje from below the bridge to the junction with the Orange support this supposition and also appear to indicate that the M.S.A. and Smithfield Man were in occupation of the Orange Valley after the Kleinpoortjie had either cut through the elevated gravel bed or followed a fault line across it. A great difficulty is to get a line of demarcation between the somewhat similar techniques yielding tools of the same type.

The high-level silts lining the banks of the Kraai and the Orange have yielded some implements of unrolled Fauresmith-M.S.A. type, but whether these implements are aberrant or were fashioned during the period of silt aggradation is difficult to say owing to the great amount of erosion that has taken place in

these silt deposits; it is remarkable that, if these implements were fashioned contemporaneously with the deposition of the silts, they should apparently be so few in number. Therefore the question of discontinuity between the Fauresmith II and the rather similar technique of the M.S.A. in the Orange Valley needs further investigation: but if there has been an hiatus, the cause is more probably related to tectonic movements rather than to a change of climate.

In the absence of any direct stratigraphical sequence, recourse was had to the separation of the various cultures by means of typology, technique, abrasion and patination; this is not an entirely satisfactory method, but it at least serves the purpose of indicating the lithic history of the Orange River high-level gravels at Aliwal North during the Pleistocene. Patination has only been taken as a guide to age when the implements have been fashioned from chalcedonic material, and then only for implements of a pre-Stellenbosch type, as chalcedony patinates much like flint and bears evidence on its surface of reflaking at various later periods. The grouping and subdivision of the various cultures must therefore be mainly correlative and based on findings elsewhere in the Union.

Description of Implements.

1. *Pre-Stellenbosch.*

   (a) Implements of Amalindan type steeply flaked from either a prepared or natural ventral plane and fashioned from chalcedonic and igneous rock pebbles, which yield a clean conchoidal fracture, the implements displaying a shape and technique somewhat similar to those described from the East London clays. (Figs. 1-5) Macfarlane (1935).

   (b) Pre-Stellenbosch implements of a Vaal River type as described by Prof. van Riet Lowe (1937) (Fig. 9).

Material. The material consists of igneous rock pebbles derived from the Drakensberg Volcanics.

2. *Early Stellenbosch.* This is represented by hand axes fashioned from igneous and quartzite pebbles, some simulating those from the Vaal River and described by Prof. van Riet Lowe as Stellenbosch I (Figs. 11 and 12). Others are even of a more archaic type and are fashioned from split pebbles, being shaped with a minimum of primary flakes; in appearance they are as old as the Amalindan or the Vaal pre-Stellenbosch types (Fig. 10). Implements which are difficult to classify are those of (a) a rough hand-axe form which has a peculiar hollow ventral plane, resulting from the removal of a large resolved flake, giving the implement a rather hooked appearance (Fig. 7), and (b) a rostro-carinate type which may belong either to the Amalindan or the Stellenbosch I.

3. *Later Stellenbosch.* Hand-axes fashioned from igneous quartzite and altered shale pebbles (Figs. 13, 14 and 15). This phase of the Stellenbosch is not as well represented as would be expected, the technique displayed is Abbevillian, with variations which include a crude Clacton. An unrolled implement of somewhat similar form and technique to that described and illustrated by Prof. van Riet Lowe (1939) as a Stellenbosch II graver was found in association with a tooth fragment of apparently equine origin. Other implements of a graver type are those of a tabular form of rough rectangular or rhomboidal section. The implements, some of which show flaking along one of the edges, have a peculiar notched curve near the point, which has been worked by a burin-like technique. The implements are thus a combination of a graver, a backed blade and a scraper, and are all fairly well rolled; it is possible that they might actually belong to an early Fauresmith (Fig. 32).

4. *Fauresmith.* This culture is strongly represented and is markedly Levalloisian in character, the culture appears to have had a very long evolutionary period in the Upper Orange basin, and without apparent breaks; fresh looking tools merge into the older in an apparent direct sequence through all stages of rolling or abrasion. Well-made hand-axes are rare, blades and points are common (Figs. 17-26), while Levallois flakes are well represented (Figs. 28 and 29). Flat scrapers (Fig. 30) with an almost vertical retouch are in evidence and have a peculiar notched curve on the perimeter forming a rather blunt nose; they appear to be related to the graver like tools already mentioned, as perhaps belonging to the Stellenbosch III. Facetted polyhedral stones were also found *in situ* in the gravels together with small discoidal well rolled scraper-like cores which have an M.S.A. facies.

5. *Middle Stone Age.* This culture is not common and is distributed rather sporadically over the gravels; it is more in evidence in the sheet-eroded soils on the Commonage in the vicinity of the brickfields and Native location. It is characterised by blades, points and discoidal cores of very fresh appearance. Goodwin (1929) has assigned to the Glen Grey industry of the M.S.A. and to the smaller points which are not uncommon to the Wilton culture, a comparable collection made by the late Alfred Brown and now housed in the South African Museum.

6. *Smithfield and Wilton Cultures.* These cultures appear be best represented in the area enclosed by the confluence of the Kraai and Orange Rivers, but no rich sites yielding typical assemblages of implements were observed.

The writer hopes to be in the position to make a further report on the Upper Orange and some of the tributaries next year.

SUMMARY AND GENERAL OBSERVATIONS.

1. Uplift along an axis, accompanied by local faulting, led to a change of course by the Orange in the Aliwal Valley during the

Fauresmith period, the ponding back of the Orange and the deposition of later silts. Phenomena of a like nature are apparent in the Valley of the Kornet Spruit near Mohales Hoek—Macfarlane (1942).

2. This axis crosses the Orange between Botha's Dam and Kleinpoortje.

3. Uplift was simple and appears to have been brought about by vertical forces alone.

4. The fault-scarps are very short and fade out quickly, possibly due to the intervention of dolerite dykes, which also appear to have modified the trends of the faults.

5. The Kraai River just above its junction with the Orange River and the Orange below the junction appear to be following along fault lines.

6. Dr. Leaky (1936) has correlated the East African Nanyukian culture with the Fauresmith and has postulated earth movements in East Africa during the Nanyukian period.

ACKNOWLEDGMENTS.

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Dr. A. L. du Toit, Prof. M. R. Drennan, Mr. J. G. F. Kruger (Town Clerk of Aliwal North), Mr. Peacock (Town Engineer), and Mr. George Visser, of the Aliwal North High School, for their generous assistance at various times.

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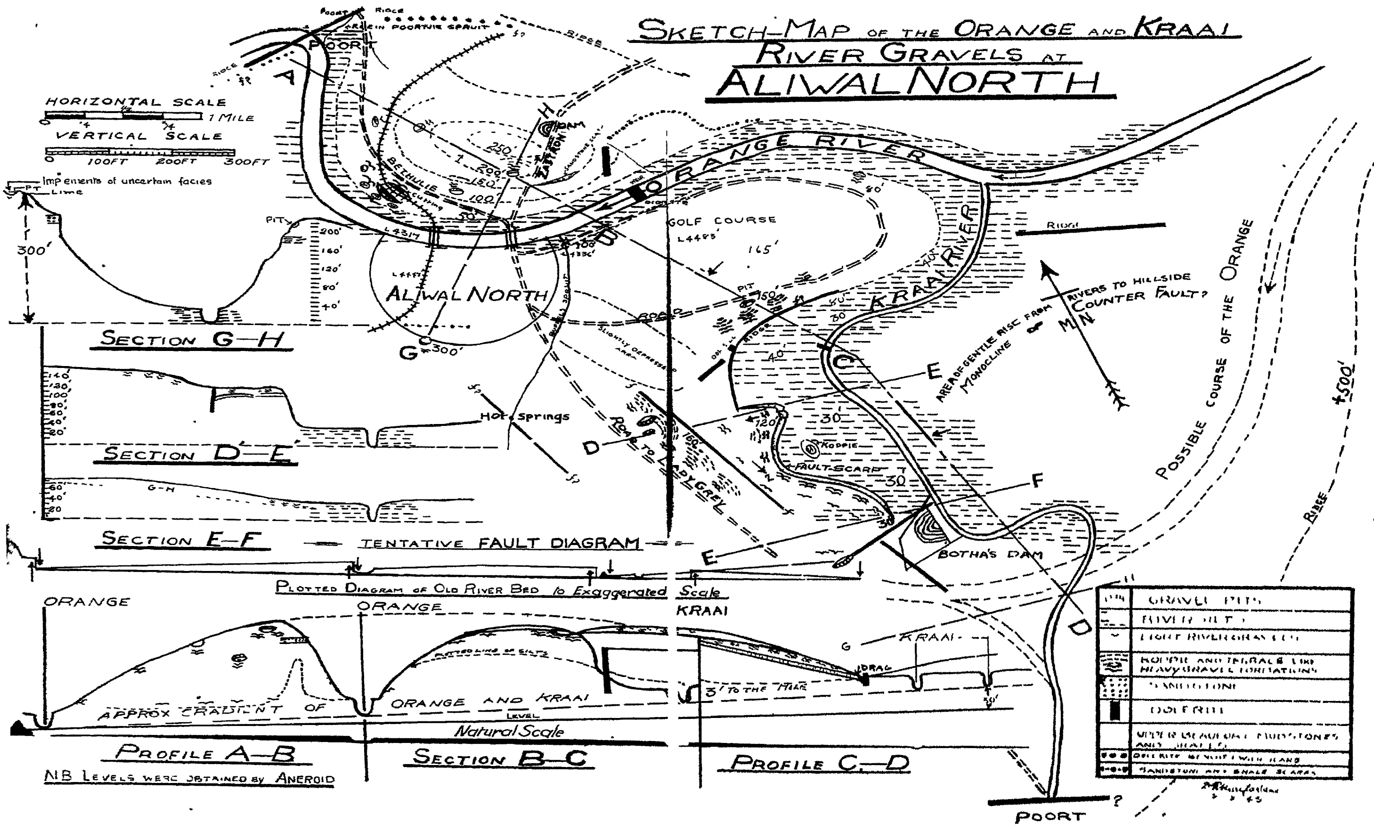
SKETCH-MAP OF THE ORANGE AND KRAAI
RIVER GRAVELS AT
ALIWAL NORTH
HORIZONTAL SCALE
1 MILE
VERTICAL SCALE
100FT 200FT 300FT
Implements of uncertain facies
ORANGE RIVER
KRAAI RIVER
GOLF COURSE
ALIWAL NORTH
BETHULIE
POORT
RIDGE
BOTHA'S DAM
KOPPIE
FAULT-SCARP
HOT SPRINGS
ROAD TO LADY GREY
SLIGHTLY DEPRESSED AREA
AREA OF GENTLE RISE FROM RIVERS TO HILLSIDE
MONOCLINE OR COUNTER FAULT?
POSSIBLE COURSE OF THE ORANGE
+500'
SECTION G—H
SECTION D—E
SECTION E—F
TENTATIVE FAULT DIAGRAM
PLOTTED DIAGRAM OF OLD RIVER BED TO EXAGGERATED SCALE
ORANGE
KRAAI
APPROX GRADIENT OF ORANGE AND KRAAI
Natural Scale
PROFILE A—B
SECTION B—C
PROFILE C—D
N.B. LEVELS WERE OBTAINED BY ANEROID
GRAVEL PITS
RIVER SILTS
LIGHT RIVER GRAVELS
KOPPIE AND TERRACE LIKE HEAVY GRAVEL FORMATIONS
SANDSTONE
DOLERITE

The attached map shows:—

1. The gravel runs in relation to the present river courses.
2. The arched nature of the former river-bed to exaggerated and Natural Scales.
3. The position of faults.
4. A tentative fault diagram.
5. The Kraai River flowing along a possible fault line.
6. The Orange River breaching the former river-bed in an apparent fault trough.
7. The position of dolerite dykes and sills which appear to have exercised some control in the trend of the faults.
8. The variable nature of the sections across the Orange and Kraai River Valleys.

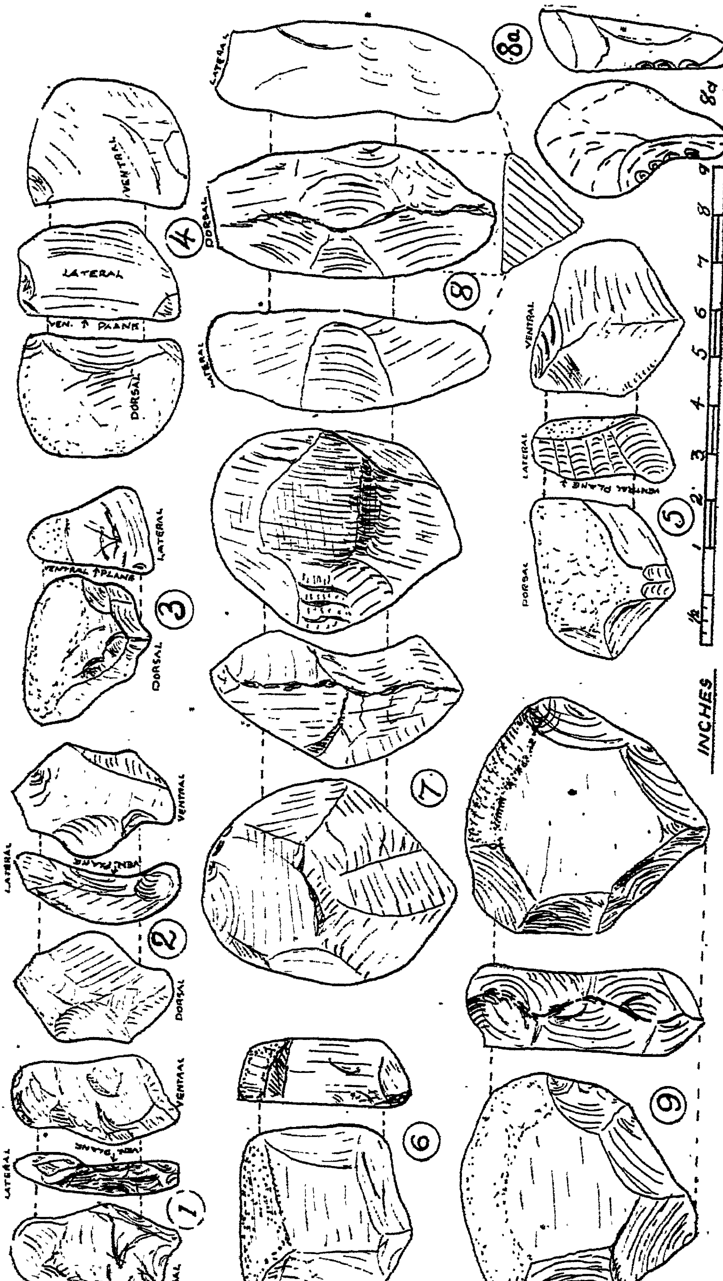

PLATE I. Figs. 1 - 6. Implements of Amalinden Pre-Stellenbosch type.
Fig. 9. Vaal River Pre-Stellenbosch type.
Fig. 7 & 8. Early Stellenbosch (?) (All from high gravels).

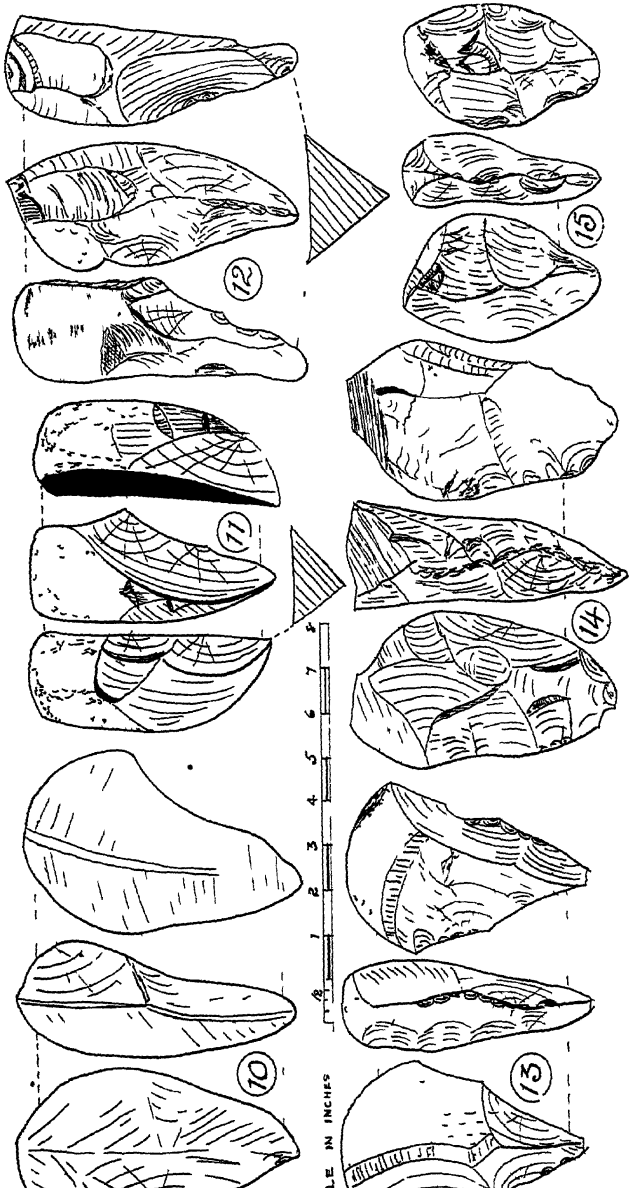

PLATE II Fig. 10. Hand-axes of Pre-Stellenbosch type?
Fig. 11. Vaal River Stellenbosch I type (Rostro-Carinate)
Figs. 12 - 15. Later Stellenbosch types. (All from high gravel.)

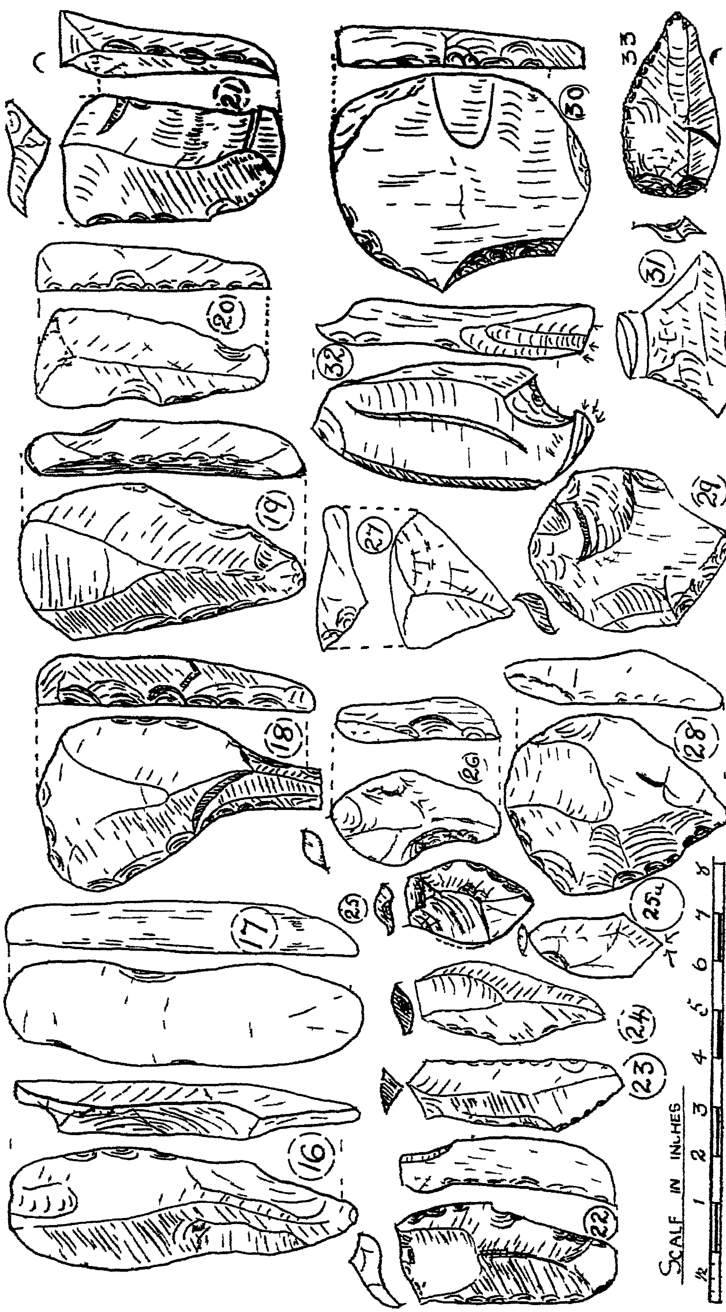

PLATE III Figs 16 - 31. Blades points and scrapers of the Orange River Fauresmith culture.
Fig 32. Graver of uncertain horizon but possibly Fauresmith (all from high level gravels).
Fig 33. Blade M.S A Fauresmith type. from later silts.

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SOME HISTORICAL BUSHMAN ARROWS

BY

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With 3 Text Figures.

Read 4th July, 1944.

In 1935 Miss D. F. Bleek presented much of her ethnological material, built up by Dr. W. H. I. Bleek and Miss L. C. Lloyd, to the University of Cape Town Ethnological Collection, where it has been on exhibition for the past eight years. Miss Bleek has recently gone to considerable trouble to copy out certain Bushman texts (collected by Miss Lloyd) on Bushman arrows, and these notes are incorporated in the present paper. The material presented includes several of the original arrow foreshafts that were discussed by the Bushman Jantje with Miss Lloyd in 1878.

The foreshafts have considerable historical importance, as they originally illustrated Jantje's description of their manufacture. It is to be remembered that these foreshafts were made by a member of the Cape Bushman tribes at the home of Miss Lloyd and Dr. Bleek at Mowbray, Cape Town, where the former Cape of Good Hope Government permitted Bushmen prisoners serving sentence for stock-theft and other crimes to reside, so that their language and customs might be studied, and their health better maintained than was found possible in the prisons of that time.

The materials used by the makers were wood and glass, which would substitute efficiently for the bone and quartz crystal or other fine-grained homogeneous stone that would normally be available to the aboriginal Bushmen. It is obvious from an examination of the wood that a metal knife was employed for trimming the foreshafts. In addition, a metal arrowpoint made by a method outside the normal range of Bushman technology has been used in one instance. Apart from these deviations, I am of opinion that these arrow foreshafts represent the native originals well. Their similarity in point of technique to the usual Bushman material was sufficiently close to have permitted Jantje to give an accurate, appropriate and detailed account of their manufacture to Miss Lloyd. So minute is the detail of this description that I was at first of the opinion that he had described the process verbally while making the arrows. This is just possible, but his interest in the "witteklip" and his scathing remarks on the badly-made

foreshaft of the iron-tipped example, rather suggest that he himself did not make them.

Before any description can be given, a few introductory remarks on the Bushman arrow are necessary to make certain terms and points clear.

General Introduction

There would seem to have been several general types of arrow in use among the Bushmen in the last century. Some of these have survived and are still in use to-day. Four seem to have been of purely Bushman origin, and five are partly the products of contact with more advanced peoples, from whom elements (or even the entire arrow) have been borrowed. These latter have the higher survival value. We may deal with the types shortly one by one before going into greater detail on types (i), (ii), (iii) and (iv), which are dealt with in Miss Lloyd's description. There are nine types, differentiated by the point, foreshaft, shaft, etc. Feathering is described later. The best independent source of information is a paper by I. Schapera ([1]) augmenting L. S. B. Leakey's paper on African bows and arrows ([2]). I have not made use of the latter paper in the present publication.

(i) Glass tips mounted on wooden foreshafts. This type forms the bulk of the present series. Distribution is uncertain, but the type is close enough to that of the Cape Bushmen to have been recognised and accurately described by Jantje. The wood and glass represent the normal tribal bone and stone. (Examples A and B.)

(ii) Wooden-tipped bird-arrows, forming part of the present series, are quite possibly an adaptation of Bantu forms, but are more likely to be a true Bushman type. Distribution fairly considerable in the Kalahari and Kaokoveld, from where additional series are represented in the University of Cape Town collection. (Examples E. and F.)

(iii) The better-known bone-tipped arrow with reversible foreshaft. This seems to have been the arrow universally used by the Bushmen of Southern Africa in prehistoric times, and is directly analogous to African prehistoric material from the rest of the continent. It is certainly found in North African Intercapsio-neolithic sites. It is the basic form to which all Bantu and other borrowed forms are adapted to a greater or lesser degree, though the essential function of reversibility may be lost in the process.

(iv) A bone-tipped arrow without linkshaft, with a quill barb or spur bound into place about an inch or two down the bone tip, and poisoned. It is not reversible. Distribution apparently confined to the Cape Bushman, and so becoming rare.

(v) Iron-tipped arrow foreshafts made from trade arrow-heads, or later from sheet iron. Distribution fairly general

to-day, though trade arrowheads are not met with outside the Cape Bushmen area. (Examples C and D.)

(vi) Iron-tipped arrows of wood, points made from sheet iron without foreshafts, or from Bantu metal. These are virtually Bantu in form. Distribution in the Kalahari area.

(vii) Iron-tipped arrows with foreshafts. Points of fencing wire. Wide distribution in Kalahari and Kaokoveld.

(viii) Imitations of (vii) in bone. Kaokoveld. Possibly made for trade, but may also be made for use.

(ix) Iron-tipped arrows of wood without foreshafts, made from fencing wire. These are direct imitations of Ambo and other Bantu forms. The main difference lies in the fact that the south-western Bantu use wrap-socketed arrowheads, whereas the Bushman series only achieves the tanged form. The forms of the blade are palpably imitations of the Bantu series.

Feathering

This classification takes no account of feathering. There are three types of feathering. The original Bushman arrow seems to have had either a single tangential whole feather, glued with wax, then bound into position at each end; or else no feather is used at all. The former is known among the Cape Bushmen and in the southern Kalahari; the latter is apparently usual everywhere with certain types of arrow. Where there is contact with the south-western Bantu, a third form is very prevalent: the use of four radial split feathers, not fixed with wax, but bound into place at each end. The type predominates to-day in the Kalahari and Kaokoveld, and the single tangential feather seems to be rarer to-day than formerly. Metal-tipped forms usually have the four radial feathers, and type (iii) is often unfeathered.

Analysis

In these various types there are certain Bushman elements that are fairly constant, and certain Bantu elements that recur frequently in certain areas. These will be defined here to avoid repetition, and the approach to the Bushman elements will be made through the basic Bushman arrow (type iii), elements of which occur constantly in other types. This arrow consists of two main portions: the reed shaft and the composite bone foreshaft. The foreshaft is made up of three parts: the bone point proper, the bone linkshaft, and the reed collar that holds them together. (Fig. 1.)

(a) The point is an elongated cone of bone, similar to a knitting needle, and averaging 10·5 cms. in length. The base, which is cut off square, is about ·5 cms. in diameter. The point is sharp, and the whole is poisoned.

(b) The linkshaft averages 11 cms. in lengths and ·7 cms. in diameter at the centre. It is an almost perfect torpedo shape, though the maximum thickness is generally slightly

towards the hinder end. It is pointed at each end, and I have not seen a round-ended example such as Schapera depicts in the work cited.

(c) The reed collar is about 2·5 cms. long and ·6 cms. in diameter. It holds the hinder end of the bone point to the forward end of the linkshaft, and is lashed with a sinew binding at each end to strengthen it and to keep it in place.

These three compose the foreshaft or harpoon-head. The foreshaft is designed to fit into the reed shaft in either of two positions. At the ready position the linkshaft is inserted into the mouth of the reed shaft so that the point protrudes. In the safe position the point itself is slipped down the hollow reed, so that the butt of the linkshaft protrudes. This protects the user from the virulent poison, and also protects the crust of poison from being rubbed off. The whole unit generally measures about 21·5 cms. in length.

(d) The reed shaft measures about ·9 cms. in average external diameter, and perhaps 40 cms. in length, though length is partly governed by the position of nodes in the reed. The reed is cut in such a way that a node supplies the butt, and a nock is cut into it, about 2 mms. wide and 6 mms. deep. At the forward end the reed is cut off square immediately behind a node, so that an open tube is left, about 15 cms. in length, sufficient to form a sheath for the foreshaft. The butt of the reed is lashed with sinew, and the mouth is similarly strengthened to prevent its splitting when the foreshaft is wedged into position.

In all types of arrow in which the shaft is of reed the preparation is similar, though there may be variety in the feathering. Similarly, whenever a linkshaft is spoken of it is of the type referred to under (b) above When we speak of a foreshaft with a flat metal point, this may consist of a metal point attached directly to an adapted linkshaft, split to take the metal (type v), or a wire point attached to a linkshaft with a reed collar (type vii). The wooden-shafted arrows (type vi) are imitations of Bantu forms, and only the lashing, insertion of the point, etc., remain to indicate their Bushman origin.

(e) The tangential whole feather is, according to Jantje, typically Bushman.

(f) The unfeathered shaft is still typical of the Kalahari Bushmen.

(g) The quill barb or spur is rare to-day, and may well have been confined to the Cape Bushmen Schapera illustrates an example (*loc. cit.*, ([1]) Fig. 3).

In contrast to these Bushman elements, we may regard the following as Bantu elements, borrowed either from Ambo, Herero or Tswana sources.

(h) Use of thin metal rod, flattened at one end. The rod supplies its own tang. Fencing wire is commonly used.

(i) Use of a wooden shaft.

(j) Use of four radial split feathers, attached either to a reed shaft or to a specially thinned wooden shaft of Ambo type.

Only one element seems to have had a European origin. This is—

(k) The flat sheet-metal arrowpoint, of a type to be described later. This is frequently imitated in galvanised sheet-iron, etc. to-day.

The wrap-socketed arrowpoint of the Ambo (made by flattening the tang of the point to a sheet, and then wrapping this about the forward end of the wooden shaft) has not, to my knowledge, been achieved by the Bushmen.

The Material

The material here described for the first time consists of a number of arrow foreshafts made by members of the Cape Bushman tribes at Dr. W. H. I. Bleek's home at Mowbray, Cape Town, and some material presented from elsewhere by Miss Bleek. This includes:

A. Seven glass-tipped arrow foreshafts of wood. (Figure II.)

B. A similar example tipped with quartz crystal or with clear-glass. (The "witteklip" example referred to by Jantje.)

C. Three metal-tipped foreshafts of wood. (Figure II.)

D. One loose metal arrowpoint.

E. Three wooden arrow foreshafts (Miss Bleek).

F. Four wooden arrow foreshafts, probably from the Kenhardt district of the Cape. (Figure III.).

G. Two Bushman poison-sticks. (Figure I.)

Examples A, B and C all consist of plain cigar- or torpedo-shaped wooden foreshafts of the type described above (under e), on the forward end of which glass or metal has been directly mounted. Examples E and F consist of similar wooden foreshafts, of which the forward ends have been variously shaped to make suitable arrowpoints.

A and B. These may be taken as identical, apart from the possibility that B is of quartz crystal. The overall length varies from 25·2 cms. to 22·0 cms., and the thickness of the torpedo-shaped wooden foreshaft varies from 1·01 cms. to ·96 cms. In each case the foreshaft is designed to fit directly into the mouth of a reed shaft.

In each example the glass tips, mounted at the forward end of the foreshaft, consist of a pair of flaked slivers of bottle glass These roughly resemble single crescents, though they also show some affinity to small "bead-borers." They may be taken as

belonging with certainty to a microlithic blade industry of Wilton or final Smithfield type.

Through the kindness of Mr. R. F. Keet, L.D.S., X-ray photographs have been taken of several specimens. These show that the tip of a wooden foreshaft comes to within ·6 cms. of the extreme tip of the wax bedding in each instance. This end is covered with wax, pressed out to a rough ivy-leaf shape, and the glass slivers are set into the shoulders of the leaf to a depth not exceeding ·15 cms. They are therefore somewhat precarious, and in use would certainly have fallen away from the wax, and have lodged themselves in the skin of the animal. One specimen fell apart, and shows that the pair of microlithic flakes was held in position by the wax alone. The trimmed edge lies embedded in the wax, the fine trimming giving a greater surface on which the wax can grip. The clean razor-like edges of the glass form the cutting edges of the arrow. The point is formed of the extreme needle-like apices of the slivers of glass. The hinder end of each is embedded in the body of the wax and does not protrude to form a barb. None of the specimens bears poison.

The fragments of glass have been flaked, not merely shattered, and each shows a bulb of percussion at the hinder end, and one or two cleavages on the opposite face. This is unlike the true microlithic technique, in which the bulb of percussion is generally discarded. The edge lying embedded in the wax is worked with tiny facets. The dimensions of the two flakes of the example that has fallen apart are as follows

	Length	Width	Thickness
1	1·31 cms.	·38 cms.	·17 cms.
2	1·3 cms.	·5 cms.	·19 cms.

In a simple test the wax employed reacted in every way (melting point, setting time, stickiness, hardness, etc.) as ordinary sealing wax. It is a dark rich brown, apparently of plant origin. The wax still retains some slight impression of finger prints. The length of the wax on the foreshaft is 2·44 cms., and is in every way comparable with the other examples Dr. J. J. Hewitt, of the Albany Museum, Grahamstown, suggests that this wax was probably made from *Pterioselastris variabilis*, a plant from which the Bushmen are known to have obtained wax.

C and D. Iron-tipped foreshafts. The loose iron arrow-point (D) is made of a fragment of sheet-metal about $\frac{1}{32}$in. thick, obviously of European manufacture. The sheet seems to have been stamped out by means of a series of small dies. One apparently formed the sides of the arrow, and a second made the nick on each side of the tang. The use of two or three dies of this sort would account for the variability of the angle of the point, etc. The arrowhead has been finished off in a sandbath to remove any burring of the edges. It has not

been sharpened. This seems to have been the form in which the arrowhead was received from the trader, presumably in Bushmanland.

The craftsmanship does not suggest an expert hand (as Jantje implies), and, as in the case of all iron arrowheads, the technique of attachment is taken over from the original Bushman methods. The foreshaft is of wood, trimmed with a metal knife, and the end is nicked to take the tang of the arrowpoint This is held in place with wax, and the end of the foreshaft is bound with string, the wax being brought over slightly to seal the binding into place. The foreshafts are of the usual torpedo shape, and measure about 24 cms. over all.

E and F. Wooden-tipped arrows. These are of the type described among the Bantu as "bird arrows," but here again they are adapted to the typical Bushman foreshaft. They are very short, measuring 10·1 to 7·1 cms. over all in length. The diameter of the foreshafts ranges from ·9 to 1·13 cms. The foreshaft has been thinned to a shank which will fit into a reed up to the shoulder. The shank varies from ·65 to ·8 cms. in diameter. The bark has been left on the central portion, showing that the wood used consisted of twigs.

The other specimens, collected by Miss Bleek from the /Xam tribe, are very similar. They measure from 8·4 to 6·7 cms. in length. One has nicks cut into the side to resemble crude barbing; the other is even more crude.

G. Poison sticks. These consist of two heavy thatching straws. Over-all length, 38 and 43 cms. respectively, each with a blob of poison at one end. These measure about 1·2 cms. in diameter, blackish, and containing some vegetable matter. On test it reacts to heat very differently from the wax. These specimens come from the Southern Bushmen.

In view of the number of papers previously published here and overseas on the Bushman arrow, I refrain from further description of types, but it would be of very considerable help to ethnology if a clear survey of types, with some study of distribution of elements, were to be made.

Klein Jantje's Notes on Arrowmaking

Concerning the glass-tipped arrows in the University of Cape Town ethnological collection, Miss Bleek writes: "The maker of these was probably /han ǂkass'ō (alias Klein Jantje, whose picture is in the 'Specimens'). He was a /Xam Bushman from Vanwyksvlei in the Carnarvon district, and was under Miss L. C. Lloyd's care from 1878-79. Whether the arrows with glass tips were actually made by Klein Jantje or not, they must have been made by some /Xam Bushman, as all the men my father and aunt had up to this date came from the Calvinia, Carnarvon or Kenhardt districts, and were of the /Xam tribe."

"It looks to me as if Miss Lloyd showed the man various arrows she had, and that he explained and commented on them."

This last seems obvious from the text, which several times implies simple action ("we do this," etc.), which may be inferred from the text but is not always described. Parts read as though iron-tipped arrows were made in front of Miss Lloyd, though the first two extracts (Jan., 1873) suggest that this is not so.

Miss Bleek then gives direct extracts from Miss Lloyd's unpublished notes. These I have re-written, closely following the original. Repetitions and the lack of pronouns seem to be partly due to the difficulty that Klein Jantje had in speaking Bushman at dictation speed. Pure repetition has been left out, and whatever is of value in the narrative has been left in, whether I have completely understood the meaning or not. In addition, I have made a few substitutions in terms, e.g., for "knife" I have used "blade"; for "furrowed stone" I use "grooved stone." I have left arrowshaft in the text, though it is quite certain from the context that it is generally used to connote what we should call the foreshaft, generally of bone or wood, in contrast to the shaft of reed.

Here and there I have made slight changes in the grammatical form employed to render the Bushman language, thus: "We grasping it bend it straight" becomes simply "We grasp and bend it straight." Apart from these alterations, the following is a complete rendering of the text as given by Miss L. C. Lloyd, and taken down from the mouth of Jantje. The items given appear in heading form under item 198 in Miss Lloyd's report (3).

VIII. 1.—6086-87. (20 Jan., 1878.)

(1) To the iron-headed arrowpoints Klein Jantje says: "This is a blade, a little blade. With these blades we shoot springbok. People have not made these nicely, for they are ugly."

(2) To the arrowhead which is apparently made with a white stone. Klein Jantje says: "This is witteklip. We use it. We fix it into the end of a reed. It is not real witteklip, but is a stone that is like a diamond."

(3) "We do not put poison on the iron arrowheads with which we shoot springbok. ' kauru is the piece of wood on which the arrowpoint is fixed" (This is the foreshaft, which is inserted into the reed.)

VIII. 10.—6923 rev. and 6924 rev. (May, 1878. A note.)

/geire ta !nwa = a feathered arrow.
!khau = arrows that have no feather.

(4) "People poison (sharp pieces of bone for their arrow-tips) with !gwe, which is red, while !ga'uoken poison is black.

Then the people feather their arrows, but they make an unfeathered arrow of the !gwe arrow. Therefore people let fly singly at the springbok, but when they feel they have no feathers, they let fly into the middle (? of the herd) and they do not see them go."

Preparing the Reeds

"Specimens," p. 361. VIII 26—8293-8302 and 8315-34. (Mar., 1879.)

(5) "We go to fetch and cut reeds. We bring the reeds, bind them with cord, and lay them in a net (for carrying). We take the reeds to the hut and divide them there. The straightened reeds are bound. This is done to the bulk of the reeds, which are put into a porcupine hole and shut in with bushes covered with earth, to keep beasts of prey from scratching them up at night. The rest of the reeds are bound and put away at home. These are the reeds that need to be straightened. We were wont to do this when the reeds were like that: we remove the reeds' excrescences by scraping, then we take the !kui stone from the fire. People make a !kui stone (grooved stone) from a split digging-stone.

(6) "We straighten the reed thus: we take the reed and lay it inside (the groove) and so straighten it. We take it out do this (looking along it) to it. If we see it is still crooked, we grasp it and straighten it with our hands. We do this: we hold it in our hands and lay it in the grooved stone. We put the stone back into the fire and take it out again. We then hold the reed and straighten the part that was bent.

(7) "We cut the (upper end of the) reed. We also cut the (other) end of the reed. We split it. First we cut its upper end, and then straighten it. When we have finished straightening it we also cut its mouth and we take out a feather.

Feathering the Arrow

(8) p. 363. "We cut the top of the feather. We take up the reed and lay down the feather to try it out. We warm the reed at the fire, and take up the /kwai (or /kwaë). In this way we rub on the kwai. We warm the /kuai (which is now on the reed) once again. We warm the /kuai, take up the feather, hold it and press it (into position), laying the feather along the reed. And we take a blade (an iron knife or arrow-head) heat it in the fire and press down the feather very nicely.

(9) "We rotate the arrow to put on the sinew binding. We first put on the sinew at the upper end of the arrow, and afterwards put on another sinew at the root of the feather. We hold and rotate the arrow. We put on another sinew at the arrow's mouth. We lay down the arrow to let the sinew dry.

The Arrow Point

(10) "We take the (fore-)shaft and shape it (by scraping with a blade), removing the peel. We warm it over the coals, and make it straight. We smoke it in a fire which flames, so that it may become black. We take up the arrowhead and warm the tip of the shaft at the fire, divide it, and put in the arrowhead. We take out the arrowhead once again and put it in the hot embers. We jerk it out with a stick and set down the arrowhead. We take up the /kuai and warm it, then put in the arrowhead. We warm the /kwai once again when the arrowhead is in the shaft. We do this: we press down the /kuai, and we take sinew and wind it on. We put the arrowshaft to dry. We stick the shaft into the earth to let the sinew dry so we can sharpen the arrowhead.

(11) "We take up another reed, straighten it, and lay it down. We take up the reed we first made straight, we take up the arrowhead and put the shaft into the reed, and sharpen the arrowhead. We sharpen it so that it bites, and we polish it on a flat whetstone of soft stone, for we intend that it become white. We lay it down.

A Second Arrow

(12) "We take up another reed, cut it, mark it, bind its mouth and lay it down. We take up a feather and beat the inside of the quill of the feather. We lay down the feather, take up the reed and the /kuai, and warm the reed. We rub the /kuai on the reed, and press the feather down on to the reed. We press down the sides of the feather with a blade (knife or arrowhead) that has been warmed. If there is no arrowhead there, we pull out the shaft and heat the end in the fire. We press down the sides of the arrow with it and bind the arrow.

(13) "We put the reed to dry while we take out the grooved stone. We set the grooved stone to cool, and leave off working so that the sinew may dry on the reed. We take up the arrowhead with the shaft on it and put it into the reed.

(14) "We lay it down and leave off working, for we feel we have finished making them, so we sit thinking of the work we shall do. So we exclaim: 'I will first be quiet. I will afterwards poison (these arrows) in the morning when it is cold, for it is warm. For the poison's heat will cover my face. Therefore I am first sitting quiet. I will poison to-morrow morning when I do not perspire. For I perspire; I do not a little perspire.' Therefore we remain quiet.

The Preparation of Poison

(15) "Therefore we shred it early on a flat stone (the sort on which the iron arrows were sharpened), and we spit our saliva into it and crush it with a driedoorn stick, making it

soft. We take a cobra's fang and (? extract) it, taking off its poison-fang membrane, the skin that covers its poison-fang saliva. We call the dried saliva or venom its poison-fang.

(16) "We put the poison-fang poison into the ku poison (the juice of the //kao plant is called ≠ku), and we crush it. We take a puff-adder's poison-fang and slice it. (In this case the skin sac is not removed, but is sliced with the contents.)

(17) "We take out the poison-fang of a different cobra, and put them together. We do this to a snake that is powerful, because we saw it at a place which is strong. This is the one from which we put in only one poison-fang. We leave its other poison-fang alone.

(18) "We put in its gall when we have cut it up. We put the rest of the gall into the ≠ku poison, and the poison becomes green and we can poison with it.

(19) "We put poison on this part, on the sinew. We do this in this way with the poison, pressing it down on to the sinew with a stick. We poison by bringing the poison down the shaft (to the lower limit of the poison, about 2⅛ inches down the shaft), and we work the poison very nicely, and let it dry. We put the end of the arrowshaft into a bush, on the back of a bush, lest a child espy it and take it.

(20) "We take the whetstone and put it away in the earth under the sticks of the side of the hut, lest a child espy it and take it and break it. We leave off working; we sit down."

Arrow Spurs or Barblets

VIII 31.—8767 rev.

(21) "//kuken=spur or barblet put by Bushmen on arrow-stems to catch in the flesh of the animal shot. A wing-feather root is used from an ostrich wing-feather. We were wont to lay poison under the root of barblet on the arrowshaft.

VIII 31.—8770-8773. (August, 1879.)

(22) "Springbok arrows have no spurs: they are clean and handsome with no spurs. Gemsbok and ostrich arrows have spurs.

(23) "A long wing-feather is cut off at the root and divided. We work with its little piece, which is small, and bind sinew over it, grasping it and laying it over the shaft. We bite off the end, the stem of the sinew which has not been on the bone. We bind on the sinew nicely, and lay down the arrowshaft for the sinew to dry before we poison the arrow.

(24) "We poison down, down, down, downwards over the stem of the spur where the sinew lies. The tip of the spur is bare. The spur is intended to catch the !kau. It is under the spur, and the tip of the spur is in the flesh. Then the poison

that is on the spur dissolves off into the flesh. Because the spur catches the flesh the poison dissolves off into the flesh.

(25) "!kau (sillin Xara) is a whitish membraneous-looking substance found near the veins of the inner side of the upper arm, and also found in the thighs."

NOTES

(2) White stone (witteklip) refers to the glass or quartz crystal arrowhead described above.

(3) When iron arrowheads are used there is no linkshaft the sliver of iron being inserted directly into the split end of the foreshaft, or //kauru. The bone foreshaft is more complex it consists of a linkshaft and a bone point, held together by a reed collar. This seems to be the type of arrow referred to in (4) as being poisoned with 'gwe. For further data on !gwe see VIII 7, 6603 rev. This is not given here.

(4) The different methods of attacking a springbok herd with featherd and unfeathered arrows are instructive. Further notes on this may be found in VIII—14. 7241-19, and VIII—23. 8067-72. These are not given here.

(5) The !kui or grooved stone for straightening arrows does not appear to be a separately manufactured implement. Though stones with a very much narrower groove than a broken bored-stone would yield do occur, they are obviously used for rounding ostrich eggshell beads and have been made for the purpose.

(6) The application of heat is, of course, essential to soften the reed while it is bent straight, hence the frequent return of the !kui to the fire.

(7) The end of the reed is cut off square. The word "straighten" here seems to mean to cut off square, or to trim the cut square. "We split it" seems to refer to the cutting of the nock of the arrow, a notch cut at a node to take the string of the bow. The mouth of the reed means the open end of reed cut below a node, and at the opposite end from the nock.

(8) kuai seems to have much the same properties as sealing wax, and obviously had to be heated constantly to allow of its being worked for a few moments. The feather is being laid on as a tangential feathering. Three spellings are given for /kuai. Miss Lloyd calls it "the substance with which the pieces of glass are made into arrowheads."

(9) Sinew is, of course, applied wet and shrinks on on drying.

(10) This treatment of the fore shaft suggests that it is of wood. This is only used with a metal tip. Hardening and darkening of wood over the coals are typical primitive practices. In this account the dry fragment of metal is first fitted into the split wood, removed, heated and finely stuck into place with

kuai. Once the whole is firmly set it can be sharpened. All this could only apply to a metal tip, as does the phrase "we intend that it become white" (11).

(12) "We beat the inside of the quill of the feather." Several feathers I have seen have either been beaten flat or split longitudinally, so that the quill lies more comfortably on the reed.

"If there is no arrowhead there." This obviously means that, if there is no metal blade handy, the feather can be pressed down on to the reed just as well by using the heated shaft and tip.

(13) This rather suggests that Jantje was going through the performance for the benefit of Miss Lloyd. "Poison's heat" probably means vapour arising from the heated fresh arrow-poison.

(14) Driedoorn or driedoring usually means a species of Rhigozum.

(16) ≠Ku poison and the kao plant. Possibly Amaryllis, as the description here is very like that given by Stow (4).

(17) This is the only reference to any "magical" or "pre-logical" thought in the whole description of what is an important social piece of work. It is difficult to say what it was intended to mean.

(21) //kuken or spur. This is not commonly used, though I have seen examples with fair frequency.

(23) "It's little piece, which is small." Probably means a sliver or fragment of feather quill, such as is actually used.

(25) "sillin Xara." Evidently meant to represent Jantje's Cape Dutch, a language Miss Lloyd knew by ear, and represented in her own phonetic system. Miss Bleek suggests that this approximates to the Afrikaans "silwer garing" or "silwer hare" (silver threads or hairs).

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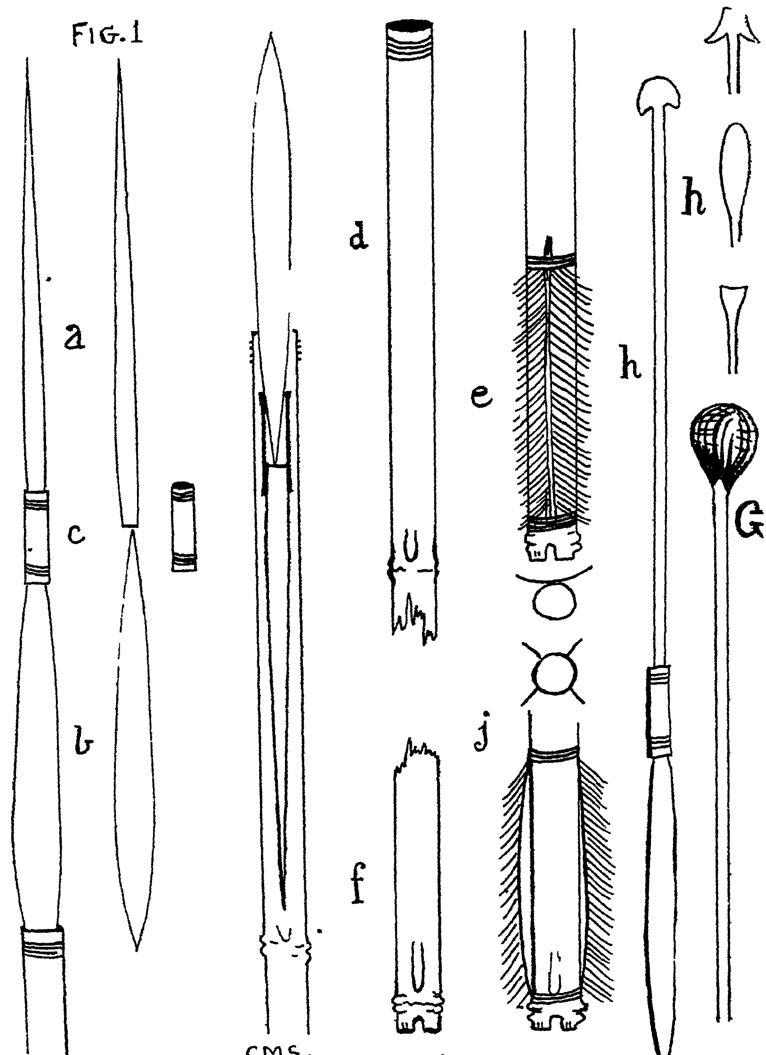
FIG. 1
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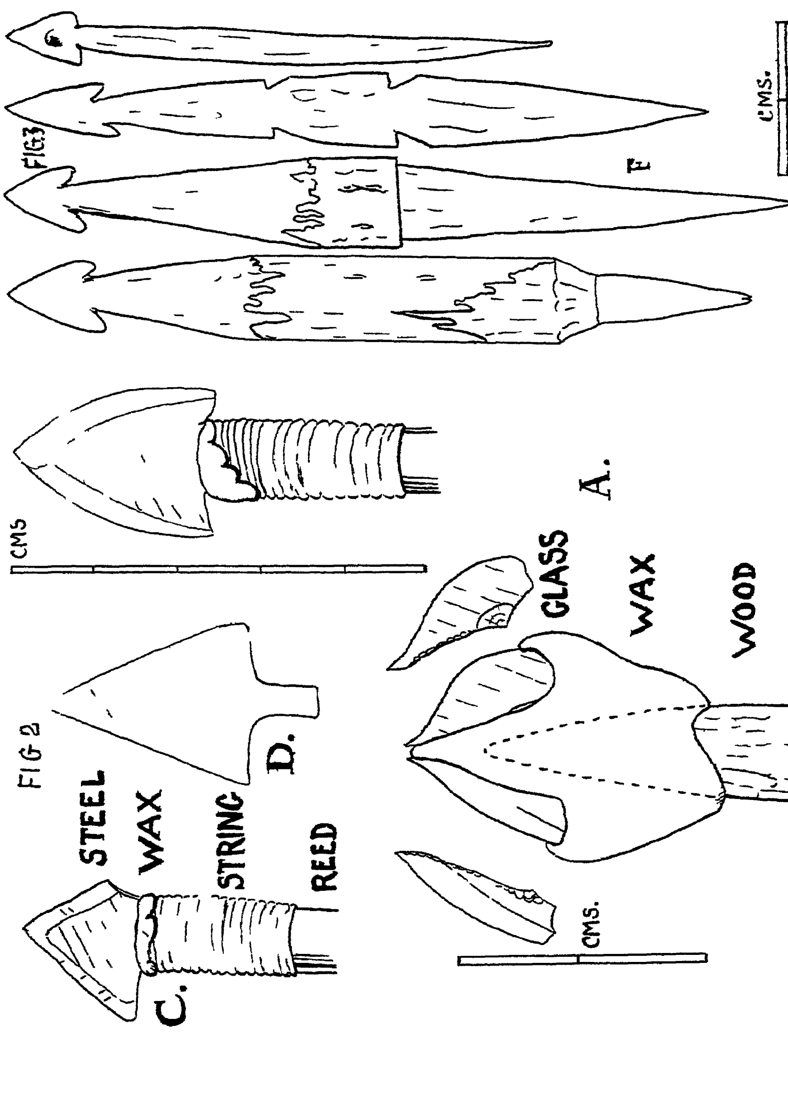
FIG 2
STEEL
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STRING
REED
C.
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A.
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WOOD
CMS.
FIG.3
F
CMS.

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POTTERY IMAGES OR *MBUSA* USED AT THE CHISUNGU CEREMONY OF THE BEMBA PEOPLE OF NORTH-EASTERN RHODESIA.

BY

Dr. A. I. Richards.
Edited by J. F. Schofield.

With 3 Text Figures.

Read 4th July, 1944.

The pottery images, which, with the accompanying descriptive notes, were presented to the School of Bantu Studies, The University, Cape Town, by Dr. A. I. Richards, are now published at the request of the Director, Mr. A. J. H. Goodwin. Only verbal alterations have been made in Dr. Richards' notes, but the Discussion, the Conclusions and the Illustrations are the work of the Editor.

The *Mbusa* are made by the *Nachimbusa*, or mistress of the ceremonies. They are fired in a slow fire made of undried chaff, set to smoulder all night. The images are then withdrawn, painted with whitewash and decorated with red dye or *nkula*.

The *Mbusa* remain the property of the *Nachimbusa*, with the exception of certain of the images which are thrown into the river at the final bathing of the girl after the ceremony, and another buried with the after-birth of the first child of the marriage. The images may thus be used again and again, but, as in practice they break very readily, they are remade, sometimes by different helpers with different designs. Each *Nachimbusa* makes her own selection from more than forty designs, and the accompanying songs, varying according to individual fancy, are taught to the candidate for the initiation. The ceremony I witnessed personally, involved the use of some thirty models.

The images may be classified under the following headings:—

(A) *Mbusa* symbolising the moral and legal aspects of marriage.

(B) *Mbusa* symbolising the economic aspects of marriage.

(C) *Mbusa* symbolising the procreative functions of marriage.

(D) *Mbusa* connected with the initiation ceremony itself.

(E) *Mbusa* symbolising other dramatic aspects of life.

THE RITES OF THE MBUSA.

The pottery *Mbusa* are carried into the Initiation Hut on the evening of the day when the girl has passed the final stage of the ceremony—the jumping over the *Mupeto*, which is formed with two crossed hoops made from two branches with both their ends planted in the ground, the one being taken from the *Mulanbwa*, or male tree, and the other from the *Mwenge*, or female tree. This signifies her transition from girlhood to womanhood.

In the evening the women of the village all gather into the Initiation Hut and after various preliminary songs and dances, the *Nachimbusa* brings in the pottery images from her own hut in a big covered basket which she places on the floor of the Initiation Hut. The women all circle round her, the candidates in front, as one by one, she takes each image and sings the song appropriate to it, always moving in rhythm with the drums which are being beaten without intermission by relays of women. The song of the *Nachimbusa* is immediately taken up by the whole chorus of the company. The image is then handed to the woman who represents the bridegroom (usually his sister) who repeats the action song, then to the girl herself, who copies the same actions. Thus in the ceremony I saw, when two girls were initiated, each song had to be sung five times—once by the *Nachimbusa*, once by the bridegroom's representative, and once by each bride. The showing of all the thirty *Mbusa* lasted from nine at night to about one o'clock in the morning, and during the whole time the two girls had to sit or sing with lowered eyes.

(A) Mbusa *symbolising the moral and legal aspects of marriage.*

1 and 2. *Mulume na Ngala* (Fig. 2, 1).—This is a dome-shaped *Mbusa* which is carried balanced on the head of the woman who represents the bridegroom. The girl kneels holding another *Mbusa*—the *Kakomba* (Fig. 1, 1)—a model of a spoon—in her hand. She pretends to pour water over the outstretched hands of her "bridegroom"—while imitating the action of rubbing over the floor with her other hand.

The company sing:—

Mwansa Chembe	Mwansa Chembe
Mwansa Chembe	Mwansa Chembe
Mulume na ngala naisa	The husband with the plumed crest has come.

Explanation.—The *Ngala* was the feathered crest worn by the chief, court dignitaries and successful warriors. Mwansa Chembe is a legendary figure of whom I could find out little. He represents the husband in his full glory to whom the wife should do obeisance.

The further song, connected with the spoon describes one of the chief ritual duties the wife has to perform for her husband —after sexual intercourse, the pair must set on the fire the

marriage ceremonial pot of water, about three inches in diameter When the water is warm, the wife must dip in a spoon and wash her husband's hands, as described subsequently.

The company sing:—

Kasambe mulume	Go and wash your husband.
We chanunga wae!	You . . . (archaic word).
Chibale! Chibale!	Chibale! (name of a mythical personage).
Na panshi tota	And do obeisance to the ground.
We chango!	You thing of little worth!
Chibale! Chibale!	Chibale! Chibale!

3. *Likosa* (Fig. 2, 3).—A *Mbusa* representing one of the bracelets (usually ivory or bone), worn by the Bemba. The pottery bracelet is slipped on the arm, or carried in the hand. while the company sing:—

Kampele mulume	Go and give me my husband, or, Go and give my husband.
Akakazanda	In the little house.
Mayo tambene	Look! Mother, look!

Explanation.—The girl shows her mother the bracelet her future husband has given her and asks to be given in marriage.

(a) It is the husband's duty to clothe his wife with bracelets and other things. This idea is later expressed symbolically when the girl has been finally washed in the river—they put on her bracelets of twisted grass saying—" Because it is the husband's duty to clothe his wife."

(b) A bracelet, usually a *nsalmo*, is brought by the boy's representative to ask for the girl's hand in marriage. The girl shows her mother the bracelet and asks for the marriage to be concluded.

Both ideas, according to answers given by different informants, appear to be expressed in this song.

4. *Mpande* (Fig. 1, 2).—A *Mbusa* representing the *mpande* shells which are cut into triangles and threaded to form the most popular neck ornament of the women. A *mpande* shell must be laid on the body of the paramount chief as it is carried to burial, and always occupies an honoured place in the ritual life of the Bemba.

The *mpande* model is waved in the hand while the company sing:—

Mpandi yandi	My beads.
Yaporia kwi sano	Have fallen in the king's court.

Explanation.—The beads represent the wife. If a man has injured his wife so that she runs away to her own people, it is as though he had dropped his beads in the Chief's Court. To regain his wife, he must approach his in-law relations with as much circumspection as he would the Chief, bringing presents and giving respect.

5. *Mwaume.*—A bowl-shaped *Mbusa*, decorated with small protuberances. It is balanced on the head, while the company sing:—

Mwe mwaume	You man.
Shiwawelua e	You are a man without sense.
Ntunda mutima e	I run in answer to your summons.
	(*Kutunda lubilo*—to run quickly in answer to a summons.)

Explanation.—The wording is obscure. My informants said immediately that the song meant that the man should provide his wife with clothes. He is a fool, without any sense if he fails in this duty. The words evidently call up some association not known to the student.

6. *Ntanda* (Fig. 2, 2).—The word means a star. A lighted torch is put inside the model and a cover placed on top of it. The girl must balance it on her head with the torch still alight, while the company sing:—

Ulekashya ntanda kashiku	You gaze at the star by night.
Ulantuka ukashika	You swear at me very much.
	(*Kukashya*—to stare at, to look at.)
	(*Kukashika*—to be serious, weighty, red.)

Explanation.—This appears to be a pun or an alliteration on the sound of *Kukashya*—*Kashiku*—*Kikashika*. The meaning given to me was that if the husband swears insultingly at his wife (*Kutuka usele*—a specially obscene form of swearing), the wife must not answer him back.

7. *Kashitu* (Fig. 2, 5).—A pot with a covering lid. This must be balanced on the girl's head while she holds the cover in its place with one hand. The song was not recorded, but it was explained as a song to teach the girl that she must feed her in-law relatives but not her own family—since the food really belongs to her husband.

8. *Mukoa.*—The Clan. This is a model, either of a little pottery basket with a bow handle, or of a lid cover decorated with small protuberances. This is swung to and fro in the hand, while a bell-shaped model, such as No. 1, is carried inverted on the head.

The company sing:—

Chyupa asenda pa mutwe	She is carrying the marriage on her head.
Uaseshya mukoa	The clan is dangling below.

Explanation.—The girl's marriage, and therefore her relatives-in-law, are to be placed in the position of honour—on her head. Her *mukoa*, clan, that is her own family, is to be carried in the lower position—in the hand. In other words the relatives-in-law are to be honoured above her own family.

Other Mbusa I have seen which could be grouped in this class, are: The Pipe—It is the duty of the wife to fill the husband's pipe for him, and the *Mwinga*—or second wife. If a woman is married as a second wife. she must honour the head wife or *Mukolo.*

(B) Mbusa *symbolising the economic aspects of marriage.*
The household.

9. *Akabende* (Fig. **2**, 6).—The little mortar which is used to husk the different forms of grain and to pound ground nuts, castor oil seeds, etc. The girl is given a pestle and imitates the pounding motion while the company sing:—

Kabenda kandi My mortar.
Makamekelo I shall pound. (?*Ku metia*—to show off.)

Explanation.—The girl is taught she must pound grain quickly for her husband, not slowly as before.

10. *Mutondo* (Fig. **2**, 4).—The big water pot used for drawing water from the river. This is balanced on the head while the company sing:—

Senda Kutondo Carry the little water pot.
Mkamwene ichalo I shall see the land (?).

Explanation.—The girl is to fetch water quickly for her husband. The fetching of water is the typical woman's service to a man. It is the woman's greeting when her husband returns from a journey, and the homage of the women of the village to a visiting chief or to Europeans on tour.

11. *Amaphwasa* (Fig. **3**, 7).—The conical heaps of clay resembling small ant-hills which are used to support the cooking-pots over the fire. The girl puts on the *amaphwasa* a *Mbusa* to represent a pot and pushes them towards the fire.

The company sing:—

Uaula maphwasa You have changed the *maphwasa.*

Explanation.—The words are probably incomplete and obscure. The meaning seems to be that the girl is to cook for her husband.

Agricultural.

12. *Mputa* (Fig. **3**, 1).—The *Mputa* are small mounds made in the gardens surrounding the villages and used for the growing of beans, peas, manioc and other non-cereal crops. They are the special property of the women, who sow and weed them after the men have done the preliminary digging. The *Mputa* model is balanced in the girl's hand while the women sing:—

Muibala	In the gardens
Teti mupite muntu	No one must pass
Nga pita muka muuame	Where the wife of the man has passed.

Explanation.—Again the wording is obscure, but I was told that it meant that it was wrong to trample over another woman's garden.

13. *Amabala* (Fig. 3, 2).—The word means "gardens." This *Mbusa* is carried out into the bush for one of the *Chisungu* ceremonies. A dance is performed round it, after a rite concerned with the different seeds eleusinium, millet, ground nuts, pumpkin, etc.

Another Agricultural *Mbusa* which I saw in use was the *Lukasu*—a model of a woman's hoe.

(C) Mbusa *symbolising the procreative functions of marriage.*

These images are difficult to procure since most of them must be thrown into the river with the girl, when she is finally bathed at the end of the ceremony. One must be kept until the girl's first child is born and then buried with the after-birth in the hut.

They include a phallic image of a man, a pregnant woman and a woman suckling four babies. The woman is supposed to be *Chyoshi na zana*—a legendary figure believed to be the first *Nachimbusa.*

(D) Mbusa *connected with the initiation ceremony itself.*

14. *Akakoni* (Fig. 1, 4).—The little bird

Song: *We Kabangula e*
We Kabangula.

Explanation.—The *kabangula* is a bird with a red crest similar to the tuft of red feathers formerly worn by the *Nachimbusa*. The girl is taught that she must honour the *Nachimbusa.*

15. *Nkoba.*—This is a bird like an egret with a shining white appearance. The model should consist of two birds perched on a stick, but one which I saw had only the stick remaining after firing.

Song: *We kakoba! Wenkoni*	You little *Nkoba!* You bird,
Shimwalaba mpemba	Do not forget the whitening.
We kakoba! Wenkoni	You little *Nkoba!* You bird,
Shimwalaba mpemba	Do not forget the whitening.

Explanation.—Part of the *Chisungu* ceremony consists in taking the girl to the river, bathing her and covering her with whitewash. She then comes back to the village and all her relatives must be daubed with a little whitewash too. The rite is supposed to make the girl white and beautiful like the egret. It marks her purification from the stain of the menstrual blood. The song illustrates this rite.

(E) Mbusa *symbolising other dramatic aspects of life.*

16. *Izwena.*—The crocodile (Fig. **3**, 3). This image is quite a realistic production in clay, but the projecting pieces are difficult to fire successfully. This *Mbusa* is held in the hand while the company sing:—

Luzamba	Crocodile (archaic).
Uikata	You catch.
Ku matete	In the rushes.
Nani shyalika	Who have they left.
Ku matete	In the rushes.
Luzamba	Crocodile.

Explanation.—The crocodile is the totem of the royal clan—and a pest very much feared—the subject of song and folk-tale. The rationalistic explanation of this song is that the girl must not dally by the river or the crocodile will catch her. But there is also the idea expressed to me "We sing the song to honour the Chief because they are all members of the crocodile clan."

17. *Chiboni Musuma.*—The Chiboni is a tree (Fig. **3**, 5).

Song: *Abusano bonse balawama*	The members of the Court do right.
Chiboni Musuma aliwama	The *Chiboni* tree is good too.

No explanation.

18. *Chyonyolo* (Fig. **1**, 3).—This is a long black and yellow centipede which appears with the rains.

Song: *Chyonyolo Mashya amataka.* The *Mashya* is a dance in which the body is distorted.

Explanation.—The words are not clear, but the image seems to symbolise the rites performed for the purification of the mother after the birth of twins.

Other similar *Mbusa*: *Bwato*—the boat; *Chumbwi*—the hyena: *Mundu*—the lion; *Fulwe*—the tortoise.

THE MARRIAGE POT OF THE BEMBA. (Fig. **3**, 4.)

The Marriage Pot (*Kamweno* or *Kalongo*—"the little pot"), is an essential feature of the Bemba marriage ritual and the life of the married woman. Each young girl is presented on marriage with this tiny pot, made and fired by her *paternal aunt*—*Nyina Senge.* After the marriage ceremony has been consummated, the pair must remain indoors all day. Next night they again have intercourse. Early in the morning, before the village is awake, the *Nyina Senge* will bring the pot to their hut. Each of them must then catch hold of the rim between finger and thumb and place it on the fire with a little water in it. When the water is warm, the girl must dip in a spoon and pour water over the hands of her husband. This is the proper purification after intercourse, and must always be performed

throughout the married life of the pair. If this is not done it is dangerous for the woman to cook, or for either of them to touch the family hearth during the days succeeding intercourse Therefore the woman must find some young girl to cook for her otherwise, either she or her husband might fall sick, or her children die. There is a special term for children who die under such circumstances—*Kupaya Mililo*—to kill by fire. Apparently this is the only plural use of the word *mulilo*—fire.

If the pot is broken a piece of the old pot must be pounded up and used with the fresh clay used to make the new pot.

This rite of purification is specially important after the ritual sexual intercourse performed to *ibausa* the village after death —*Kusangululo muski*, or pestilence; or at the inheritance of a chieftainship.

The marriage pot of the *Chitimukulu*, the Paramount Chief is specially important—it is a larger iron pot—handed down from time immemorial and guarded by a special priest—the *Chimba* Without the possession of the pot the chief cannot come to the throne. Having seen it at his accession he hands it back to the keeping of the *Chimba* and a special new pot is made for him for use after the ritual act of intercourse with his head wife which is an essential part of the Accession Ceremony.

The Missions now working in the Bemba territory have sternly discountenanced the use of the marriage pot, with the result that there is now a great feeling of secrecy about the whole rite, and it is difficult to secure the pots.

(Signed) A. I. Richards.

Discussion.

There are 17 images in this collection of *Mbusa*, of these 15 can be identified from Dr. Richards' illustrations and the accompanying text. They are:—

1. *Mulume na Nyula*	(Fig. **2**, 1.)
2. *Kakombe*	(Fig. **1**, 1.)
3. *Likosa.*	(Fig. **2**, 3.)
4. *Mapande.*	(Fig. **1**, 2.)
6. *Ntanda.*	(Fig. **2**, 2.)
7. *Kashitu.*	(Fig. **2**, 5.)
9. *Akabende.*	(Fig. **2**, 6.)
10. *Mutondo.*	(Fig. **2**, 4.)
11. *Amaphwasa.*	(Fig. **3**, 7.)
12. *Mputa.*	(Fig. **3**, 1.)
13. *Amabala.*	(Fig. **3**, 2.)
14. *Akakoni.*	(Fig. **1**, 4.)
16. *Izwena.*	(Fig. **3**, 3.)
17. *Chiboni Musuma.*	(Fig. **3**, 5.)
18. *Chyonyolo.*	(Fig. **1**, 3.)

Three other *Mbusa*, the *Imgala*, (Fig. 3, 6), *Sonoa* and *Kalamo* are not mentioned in the text. Unfortunately the name lables of the last two have become detached and all we know about them is that one of them is represented by (Fig. 1, 5), but which it is we cannot say.

All the *Mbusa* show considerable skill in the potter's craft, for the clay is fine and the pieces are well fired. Nearly all the models have been completely covered with a liberal coating of whitewash, in others part of the figure has been so treated and the remainder has been left the natural colour of the pot. In the case of only one image—the *Amabala* (Fig. 3, 2)—can we be certain that the red dye, *nkula*, has been used. The use of white is a trait of many of the initiatory rites of the Bantu and is found amongst widely separated tribes. For example, the models used by the Venda in their *Ngoma 'si ngwele'* are partly coloured with white (Stayt, pl. xxxi), and many other cases could be quoted.

Another characteristic of our *Mbusa* is the way in which they are decorated with blobs, projections and cusps of clay sometimes covering the greater part of the surface of the object. A similar kind of surface treatment has been found on a number of articles of unknown origin which were found about twelve years ago near the confluence of the Umfurudzi with the Mazoe river. It is not altogether improbable that the mammilae of the *Musuku* or " top hat " ingots of the Venda had a similar origin, for at least some sort of relationship is suggested by several of the Mazoe articles.

As the *Mbusa* are made of well-burnt clay it is reasonable to expect that either they, or similar objects should be discovered on sites which have been occupied in the past by Bantu people who enjoyed a similar culture to that practised by the Bemba. We believe that such is indeed the case as the following notes will show. We have also noted instances in which objects made of less permanent materials but having a similarity in form are used by present day Bantu peoples in their initiation ceremonies.

1. *Malume ua Ngala*.—This *Mbusa* is a pine-apple shaped vase with an irregular hole at the apex. It is about 8 inches in height and has a rather greater diameter. Practically the whole surface is covered with little excrescences resembling worm-casts. The clay is fine and very well burnt. One half of the *Ngala* has been whitewashed but the other half is a reddish buff, probably from the natural colour of the pottery.

The obvious affinity of the *Ngala* is with the *Sali*, used in the *Domba* ceremonies of the Venda (Stayt, p. 117). Stayt has described the *Sali* as being a solid conical object, about 12 inches in height, made from a mixture of ashes, earth and cow-dung. It is covered with mealie grains coloured red, white, yellow and black, arranged in irregular vertical strips, with two white ostrich feathers stuck in the apex as decoration.

We are not told if feathers are ever used with the *Ngala*, but the reference in the song to the " plumed crest," and the presence of the little hole in the apex, makes it not unlikely that they were.

2. *Kakombe*.—This little spoon has been rather roughly finished. The outer side of the bowl has been decorated by working up the clay into a series of vertical ridges. The whole object has been well covered with whitewash.

A number of pottery spoons were found on the Limpopo River site of Bambabandyanalo (Fouche, pl. xxxi. 1a), but none of them were decorated in any way.

4. *Mapande*.—This model is completely covered with whitewash. Its resemblance to the conus shell, which is so extensively used for making ornaments in Central and South Central Africa, is not particularly striking, but probably the ridges on the upper surface have reference to the triangular pieces into which the shell is cut by the Bemba.

Beads and discs, cut from the central column or the flattened ends of the conus are amongst the earliest recorded ornaments used by any Central African people. Dos Santos, writing towards the end of the 16th century calls them "andoros" and tells us that the " Monomotapa and the Mocarangas his vassals, wear a white shell on the forehead hanging from the hair, as an ornament, and the Monomotapa wears another large shell on his breast" (Theal, vii, p. 289). To-day these shell ornaments are called by the Venda, *ndalama*, and by the Pedi, *ditalama*, both of these words being derived from the Greek *drachma* through the Arabic form of *dirhem*.

Mushroom-shaped objects have been recovered from the Limpopo Valley sites, as the heads of several of these had been pierced by three holes, grouped round the central stem, it has been suggested that they had been used as stoppers. Similar objects have been found recently in a filled-in shaft of an " ancient " gold working at the Golden Shower Claims, Arcturus. In these the head has neither ridges nor holes, but in some of them, the tip of the stem has been pierced by a small vertical hole. The clay, unlike that of the Limpopo specimens, is so soft and badly burnt that it is improbable that they could have been used as stoppers and we may therefore class them with our *Mbusa*.

5. *Mwaume*.—From Dr. Richards' sketch it would appear that this *Mbusa* is similar in shape to the *Amabala* (Fig. **3**, 2).

6. *Ntanda*.—This *Mbusa* has not been as carefully made as some of the others but it was well burnt and completely covered with whitewash. The one in the collection shows no sign of having been used for the purpose described.

7. *Kashitu.*—This object was roughly made. The whole of the exterior has been covered with whitewash, but the interior of the pot has been left with the original blackish colour of the clay.

8. *Mukoa.*—Precisely similar pottery baskets with bow handles as illustrated by Dr Richards have been found on the Limpopo sites.

9. *Akabende*—This object has been covered with whitewash both internally and externally.

10. *Mutondo.*—This *Mbusa* is a little spherical pot with a wide mouth, 7 inches over the rim and a short flared neck. The rim was flattened and the whole of the exterior covered with elongated excrescences. Both the inside and the outside have been whitewashed.

11. *Amaphwasa.*—This cone-shaped *Mbusa* is covered with similar excrescences and has been completely whitewashed.

12. *Mputu.*—This model is in the form of an inverted bowl, the exterior is covered with fin-like projections. A central zone has been left the colour of the pot—greyish black—while the sections on either side of it have been whitened.

13. *Amabala.*—The interior of this bowl-shaped *Mbusa* has been left black—the original colour of the pot—while one half of the exterior has been coloured red and the other half has been whitened.

Human Figurines.—Unfortunately none of these figurines are included in the collection. The use of wooden images in the initiation ceremonies has been recorded from several Bantu tribes, for example, the Venda. as already noted, the Lenge and the Chopi (Earthy, p. 110). At Bambandyanalo a number of female figurines and two male figurines have been discovered. these, like those of the Lenge, carry the tribal cicatrisation markings, which on the Limpopo Sites and in Chopiland, are reproduced on the pottery. Another pottery figurine of a man with facial cicatrisation markings formed part of the material discovered in the Mazoe Valley. A number of soapstone figurines were discovered many years ago at Umtali and illustrated by MacIver (MacIver, pl. xiv and xv). From the number of objects represented, which have their counterparts amongst the *Mbusa*, it is not improbable that they had a similar use.

14. *Akakoni.*—The little bird represented by this image is whitened all over. Several soap-stone figurines of birds were found at Umtali.

16. *Izwena.*—The crocodile model was roughly whitened on the upper surface of the back and sides only the underneath being left the colour of the pot.

The crocodile is the sacred emblem of a number of Bantu tribes, amongst whom we may mention the Kwena, the Koni and the Venda. Regarding the latter, Stayt tells us that the "crocodile is closely associated with the Venda chiefs and regarded by them as a sacred object," and a stuffed crocodile was an essential part of the furniture of the chief's sleeping hut (Stayt, p. 204).

17. *Chiboni Musuma.*—This model has been formed by welding together leaflike pieces of clay, it has been whitened all over.

18. *Chyonyolo.*—This model of one of the millipedes has been very skillfully made and has been whitened all over.

Various Models.—There are a number of *Mbusa* mentioned in Dr. Richards' notes, but which are neither illustrated in her sketches nor represented in the collection. These include: the pipe; the *Mwinge*, or second wife; the *Lukasu*, or hoe; the *Bwato*, or boat; the *Chumbwi*, or hyena; the *Mundu*, or lion; the *Fulwe*, or tortoise. These *Mbusa* may be connected with the finds of pottery figurines which have been made on a number of sites—for example, the giraffe and cattle from Mapungubwe, a sow from Zimbabwe, an elephant and other fragmentary figurines from Arcturus. The Umtali figurines include human beings, animals and domestic utensils—forming the closest parallel to our *Mbusa*. The Venda make use of the clay model of a bull in the *Ngoma kholomo ya Duma* rite and the hyena, or *Phiri* plays an important role in the Pedi initiatory ceremonies.

In addition to these there are two *Mbusa* which are represented in the collection but not mentioned in the notes. Of these the *Ngalà* (Fig. 3, 6) probably belongs to the Agricultural Group. The exterior is covered with small cusps and is whitened, the interior is left with the original blackish colour of the pot.

The *Mbusa* illustrated at Fig. 1, 5, is very probably a model of an animal. It is covered with whitewash with the exception of the head and neck which are left the original grey colour of the pot.

Conclusions.

We believe that this study of the Chisungu Ceremony of the Bemba will support the following conclusions:—

1. The Bemba ceremonies have much in common with those of other Bantu tribes, particularly the Venda and the Lenge.

2. That the *Mbusa* of the Bemba have their counterparts in objects—mostly made of wood—used in the initiation rites of other Bantu people.

3. That these pottery *Mbusa* are nearly akin to, and may explain the uses of certain anomalous objects from the number

of archaeological sites, particularly Umtali, Arcturus, Mazoe Valley, Mapungubwe and Bambandyanalo.

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Description of Text Figure No. 1.

1 *Kakomba;* 2, *Mpande;* 3, *Chyonyolo;* 4, *Akakoni;* 5. unknown.

Description of Text Figure No. 2.

1, *Mulume na Ngala;* 2, *Ntanda;* 3, *Likosa;* 4, *Mutondo;* 5, *Kashitu;* 6, *Akabende.*

Description of Text Figure No. 3.

1 *Mputa;* 2, *Amabala;* 3, *Izwana;* 4, *Kamweno:* The Marriage Pot; 5, *Chiboni Musuma;* 6, *Imgala;* 7, *Amaphwasa.*

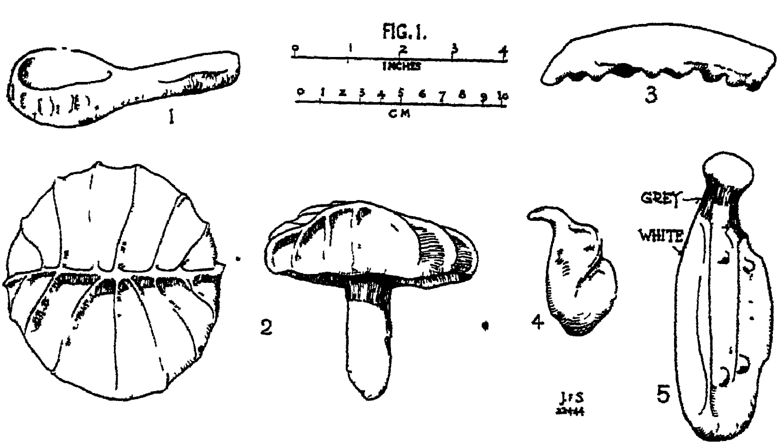


FIG. 2

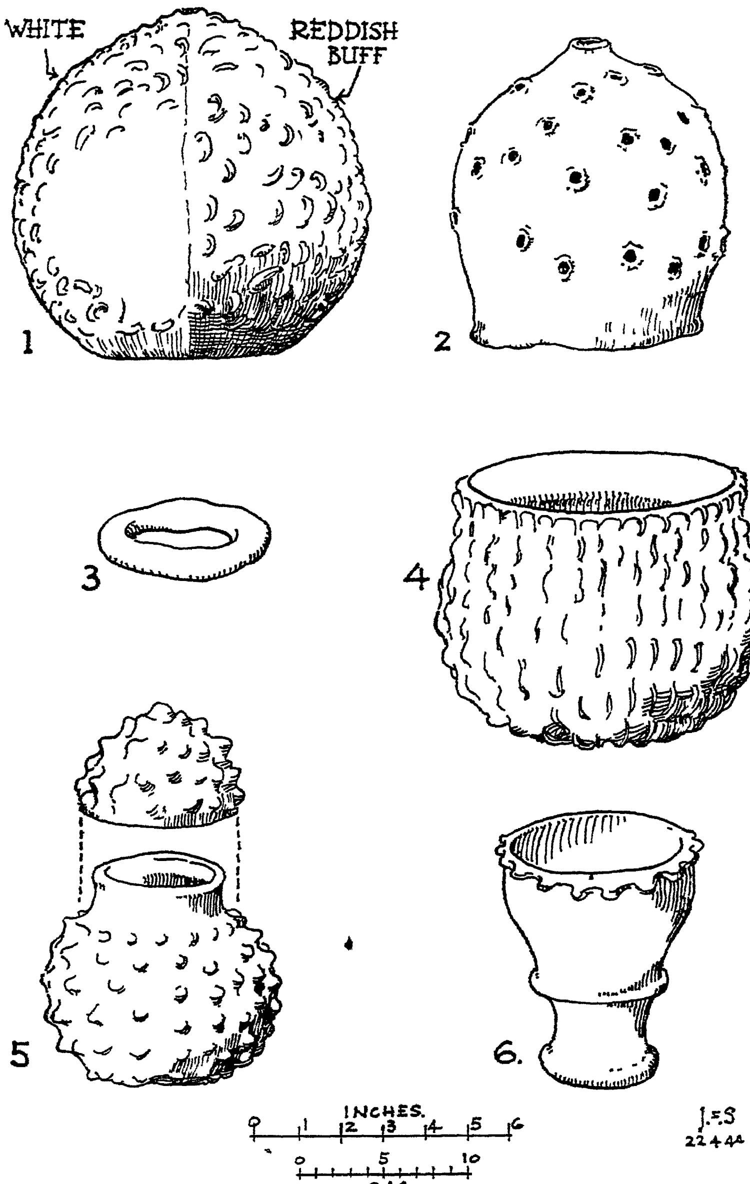
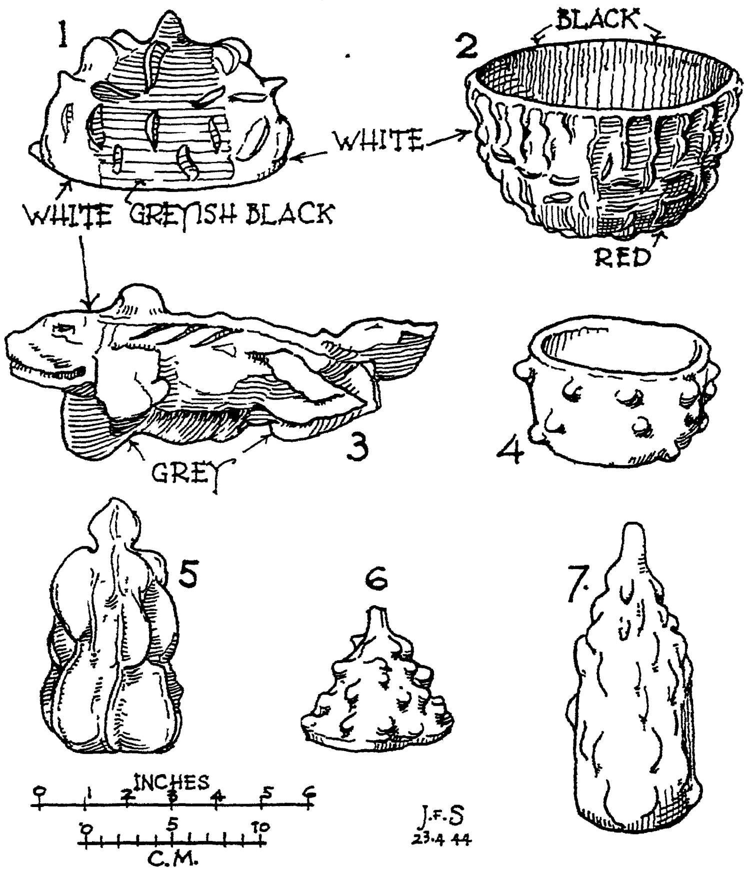


FIG. 3.


1
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2
WHITE
WHITE
GREYISH BLACK
RED
3
GREY
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7.
INCHES
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A MIDDLE STONE AGE INDUSTRY FROM PRIMROSE RIDGE DISTRICT, GERMISTON, TRANSVAAL

BY

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29 Beaconsfield Avenue, Primrose.

With 2 Plates.

Read 4th July, 1944.

On Primrose Ridge trenches for house foundations dug in error on Plot 170, Primrose Hill Township, brought to the surface white quartz flakes. The whole ridge had been my hunting ground for years, and many artefacts had been collected from the surface, weather-stained and patinated.

The fresh sharp chips from a new trench suggested a factory site, and in a brief search an ovoid bifaced point, in white quartz, of beautiful workmanship, was picked up. Shaped like an old-fashioned "ear-drop," a pointed ovoid, maximum dimensions, 2 inches by $1\frac{1}{8}$ inches by $\frac{3}{8}$ inch, it is finely pressure-trimmed on both surfaces, and, except for $\frac{1}{8}$ inch missing at the tip, is in "mint" condition. (Plate Y, No. A1.) Since then some 800 fine artefacts have been recovered from this site, but this first specimen is still, in some respects, the gem of the collection.

A grant from the National Research Board and Council enabled me to undertake excavations over a period of two months. The site is just below the crowning wave of six feet high rocks, on the north-facing slope of the ridge, a sunny area all day and sheltered from the south winds. It was evident, before excavation ceased, that it had been a primitive camping ground for many centuries, as an 18 inch bed of stratified soil had gradually accumulated on the underlying red and yellow shale, which, elsewhere on the ridge, outcrops on the surface.

Material from an area of 50 feet by 15 feet to a depth of 18 inches, was put through the sieve, the method used being to mark off a section and remove it in 15 inch widths. 5 inches deep, then a second layer of 5 inches, and a final layer of 8 inches brought us to the bedded shale, red or yellow, which formed the bottom. From the first day the site was a rich one, and, in some 42 working days, from thousands of artefacts which came up on the "hook," or were selected from

the sieve, 800 specimens worthy of display were finally sorted out. (No pick was used; we pulled up the surface turf with an iron hook, and all work was so done, in a lifting motion. to get the specimens out undamaged.) The soil was not hard set, and this hand-hook implement brought up everything easily, except certain firm boulders, most of which, by the scars and excess of chips about them, had served as anvils in situ.

Classification of Specimens.

Sorting by types suggests or indicates a new individuality to this site, as the groups most heavily represented are in two cases unique, and in the fact that the ordinary Middle Stone Age South African types are poorly represented numerically when present at all.

The most frequent type, of which there are more than 60 specimens (Plate Y, 1, 2 and 3) is best pictured as resembling an up-turned boat, averaging 3½ inches long, 1 inch keel height, and 1½ inches deck-with or flake surface.

For this new type the style of "Carinated Point" has been suggested; but—is it a "point?" My suggestion, based on its shape entirely, is "*Navis*," and this distinctive and descriptive title, I hope, will be permitted. Another fine type well represented is a pointed ovoid bifaced blade or spear-head (Platé Z, B and C) averaging 3¾ inches long, 1¾ inches wide, by ½ inch thick. In dark quartzites, delicately pressure trimmed on both sides, there are twelve of these. (Note: No chips of this dark quartzite were found in all the sievings.)

A type of side-scraper which is best described as "Tomahawk" shaped, is represented by 15 specimens in quartzites and quartz. (Plate Z-F.)

Out of 800 specimens there are only six typical points comparable with the "points" common in the Pietersburg Culture. (Two are shown, Y, 6 and 7.) Two equilateral triangular "points" with transversely concave flake undersides, carefully trimmed on the upper or convex face, are an interesting variety, which might have been regarded as fortuitous if only one had been found· both are concave flakes, similar in shape and trimming. (Plate Y, 11, 12.)

Many of the quartz and quartzite specimens are in "mint" condition, clean, unweathered and undamaged.

Outstanding in this respect is the largest specimen found, an ovoid biface, measuring 6 inches by 2¼ inches by 1 inch (Plate Z, A) with edges finely pressure-trimmed, geometrically symmetrical, in cream-coloured granular quartzite. In the smaller types over 100 chert specimens, of many varieties, are in good condition, with a rich creamy-yellow lustre; many are choice examples of delicate trimming, in points and blades and scrapers, and show remarkable skill in flaking. A fine side-

scraper (Plate Z-H), a long point on flake (Z, J), and a coffin-shaped biface (Z, E) are outstanding.

In shale, a material in which good specimens seldom survive, over 70 specimens with secondary working were recovered Plate Z, D illustrates a nice biface in this material, although all sharpness is dulled by weathering.

Illustrations in the plates will convey the appearance of most types indicated, but the Navis type requires a fuller description. Plate Y, 1, 2, 3 shows the top and a section of 3 of the 60 specimens of this type. It lies naturally on its flake surface, with its ridged or keel side up. Nearly all have sharp points, but there are three varieties of the butt. Out of 60, half have rounded butts, eighteen (18) have truncated butts (of which some may be due to accidental breaking), and twelve (12) have both ends pointed. All are high backed, the ridge approximating two-thirds the width of the flake surface (as, width 1½ inches, ridge 1 inch). There are all colours of quartzite, from blue-gray and olive green, through opalescent agate-like material, to white quartz, of which there are three examples. It will be interesting to know if there are any specimens of this type, the Navis, in other collections.

The ovoid biface type (Plate Z, B and C) suggestive of spear heads, is also remarkable. No single specimen equal in symmetry, workmanship or state of preservation is to be found in the fine collection stored in the cases of the archaeological survey in Johannesburg. For 12 such specimens, in fresh dark quartzite, to be found in one area proclaims this a remarkable site. In cores, some of the small ones are not unlike some found with advanced Fauresmith artefacts at Healdtown. They are in shale or chert, with one in quartzite, small upright cylindrical cores, fluted and showing signs of having been used as fabricators at their bases. Another small type is best described as "Tea-cosy" fabricators (Plate Y, 4 and 5) from 1 inch to 2½ inches long in quartz and quartzite.

Cores in general. Among the larger are several drum-shaped core-fabricators, with one large horse-shoe shaped specimen in yellow quartzite. Classifying the forty odd large specimens in quartzite is a job for future leisure and careful comparison; indeed, as my work is incomplete, many which may be of value may still lie in the debris-heaps on the site, but all the most obvious purpose-made or select are safely "gathered in."

Spheroids, bolas, etc. Of these, mostly very fine spheres, 13 were found from marbles to polo balls in size, and in different materials varying from iron to a granular loose grained dark rotted granite. The spheroids in 11 out of 13 are very true and shapely. In the smaller artefacts I find I have not done justice to the very fine delicate bifaced points in white quartz. Well shaped, with rounded butts, and finely trimmed, these form a group bespeaking highly skilled technique in this

difficult material. (Plate Y, 8, 9, 10, and Plate Z-G.) They average 2 inches by $\frac{3}{4}$ inch by $\frac{1}{8}$ inch. In chert and shale, some very delicate, thin blades were recovered, 3 inches to 4 inches long, 1 inch wide and little over $\frac{1}{8}$ inch thick. One shorter one is finely serrated, some 24 " teeth " to the inch. Some chert specimens and one in quartz, appear to have had a reducing flake trimmed off the upper side (Plate Z-K) leaving it slightly hollow, with an even trimmed rounded border.

The prospects. To show that the site excavated is only the first of many which should be tested on the ridge, I may state that on the last day of the " dig " a trial trench was made on the plot immediately to the east of 170—(on 171), at a level 25 feet perhaps, lower and 100 feet further down the hill. There, from an area 6 feet by 3 feet and 10 inches deep I recovered, with the hook, some 60 specimens in an afternoon! It seems fair to conclude that good archaeological finds may be made on many of the ridges along the Reef.

To sum up, it seems right to state that from the novel types found in considerable numbers on Plot 170, and the delicacy of the workmanship, the extensive use of chert and white quartz, and the perfect symmetry of a large proportion of the specimens, and the paucity of the Pietersburg type of points—6 only in 800, and the fact that one and one only, typical *coup-de-poing* type of biface of Pietersburg style—(a very nice well balanced specimen, 4 inches by $2\frac{1}{4}$ inches by 1 inch was recovered), one is compelled to conclude that this is not a Pietersburg culture but stands as a new type-centre, with novel ideals, fuller use of certain materials, the full use of chert for finer tools, and as a climax the use of white quartz in the delicate bifaced round-butted small points (Plate Z, G and Plate Y, 8, 9, 10) so plentiful on this site. The attention of archaeologists might perhaps be drawn to this distinctive industry by some specific designation, such as " The Primrose Ridge Culture," in order to promote the full investigation of an easily accessible area already giving promising results.

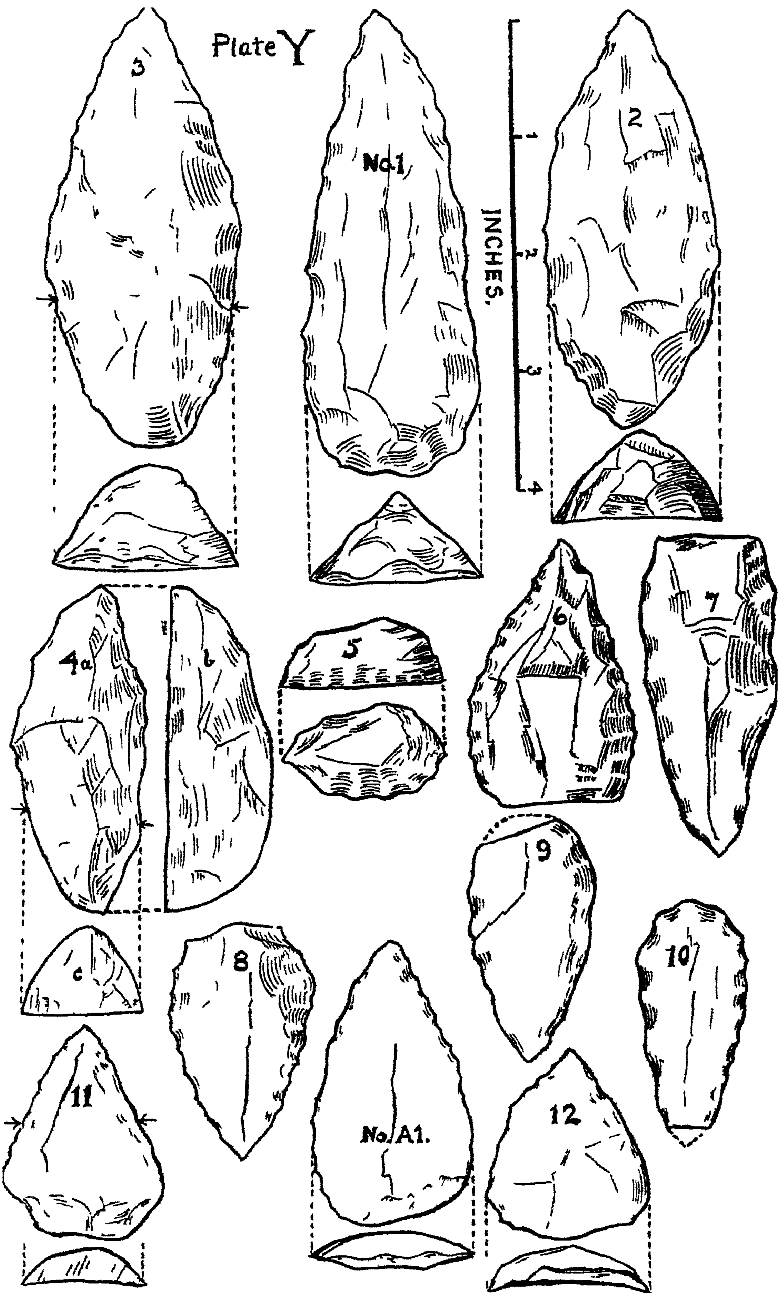
Plate Y
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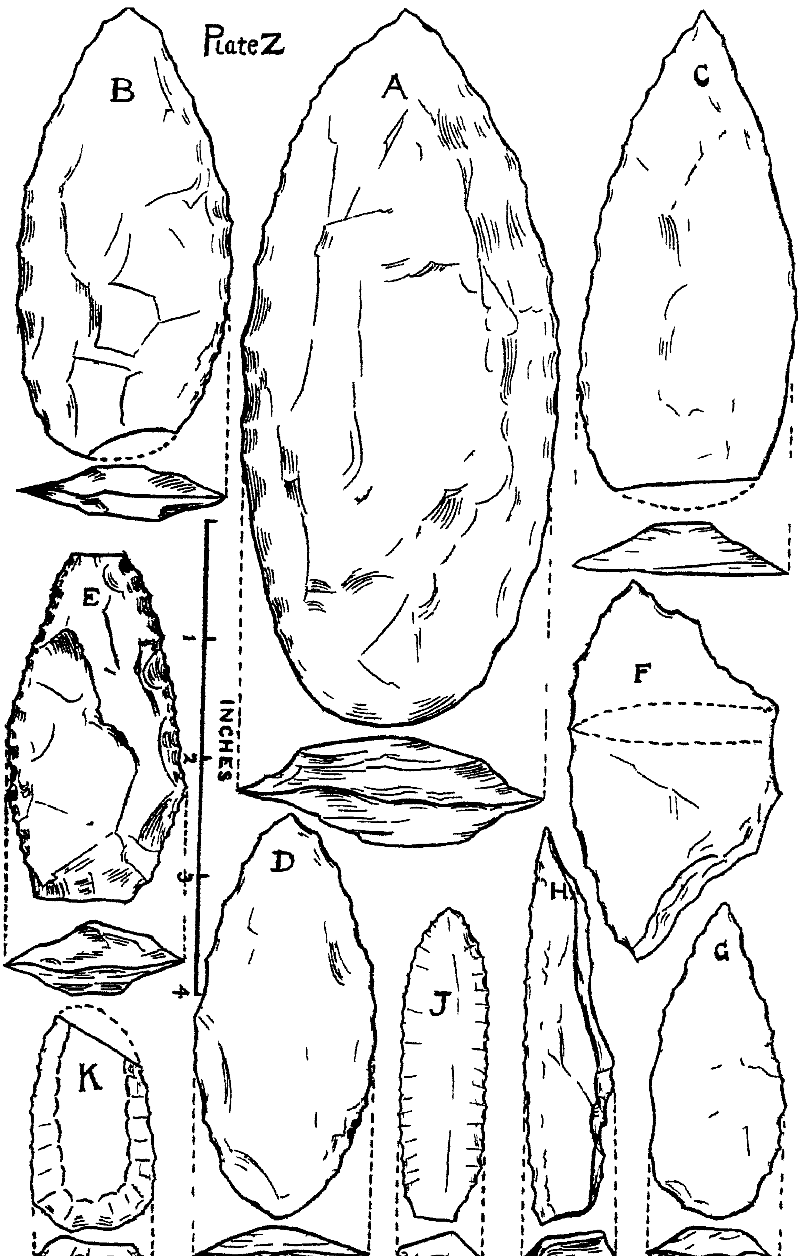
Plate Z
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INCHES

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NOTES ON THE SALT-MAKING INDUSTRY OF THE NYANJA PEOPLE NEAR LAKE SHIRWA

BY

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With 3 Text Figures.

Read 4th July, 1944.

Introduction

Lake Shirwa lies some 16 miles due east of Zomba Plateau and some 25 miles due north of the Mlanje massif, in the Nyasaland Protectorate. " It has a maximum width of about 16 miles and a length of about 30 miles, but its extent varies greatly according to the variations of rainfall and evaporation. The lake is shallow and has no outlet, and consequently its waters are brackish, particularly towards the end of the dry season. (1)

The lake receives the drainage of the eastern slopes of the Shire Highlands as well as part of the drainage of Zomba Plateau and the Mlanje massif. The soil round about the lake is very marshy during the rains, and tends to become friable in hot weather. The lake is some 1,700 feet above sea level.

The plain situated between Zomba, Mlanje and Lake Shirwa is known as the Palombe plain, and takes its name from the Palombe river, which has its rise on the northern slopes of Mlanje mountain, and after flowing about 20 miles in a north-westerly direction and then 20 miles in a north-easterly direction has its embouchure at the most south-easterly point of Lake Shirwa.

The villages to the west of the lake are those of the Nyanja tribe (*nyanja*=lake, stream). To the south of the lake various sub-divisions of the Lomwe people are found, while to the north of the lake the Yao tribe predominates. Between the Palombe river and the Naisi river further north the Nyanja tribe is found with very little admixture from other tribes.

The centre of the local salt-making industry is a village called *Kanthebwe*, which is situated on the north-west banks of the Palombe and about three miles from the lake shore.

The Materials Used

Salt is made on the Palombe river either from *lenjere* weed and other lake-side weeds, or from saline soil which is found in patches near the lake.

1. *From lenjere weed.*—*Lenjere* is a floating weed found on Lake Shirwa. There is another similar weed called the *bawe* weed. At Kanthebwe village salt is usually made from saline soil, but when the lake has remained at a low level for some time and there is no saline soil to be found women gather the *lenjere*.

> "*Amadula njeza ndi kutira mbuwa imodzi lenjere pansi. Aoca ku nyanja ndi kubwera kugona ku mudzi. Mamawa atenga fulusa lace.*"
>
> They cut *njeza*(²) and throw it on a heap with *lenjere* at the bottom. They burn it at the lake and return to sleep at the village. In the morning they collect the ashes.

Another informant said that they had found that *njeza* yielded stronger salt than *lenjere*. When I asked why *lenjere* was used at all, he said: "They have found that it is good to mix the two grasses." This informant also said that it did not matter which type of grass was put at the bottom of the heap Another salt-maker said that they mixed the two grasses because the ashes of the *njeza* blow away easily, but when mixed they grip each other (*igwirana bwino*). When I asked why they trouble with the *njeza* at all, she said that they grow together. After being burnt the ashes are treated in the same way as the saline soil, as described below.

2. *From saline soil.*—Surface soil is taken, according to my informants, from places near the lakeside on the N.W. side of the Palombe river which have been covered recently by the lake water during the rainy season, and where it is still damp under the surface. I visited one such place about three-quarters of a mile from the lake and a similar distance from the banks of the Palombe. There were old rice gardens quite near, and the *bango* reeds which grow in the marshy approaches to the lake began about a quarter of a mile away. The saline earth was covered with a short grass about 18 inches high, but in some places this had been burnt off. So far as I can discover the saline soil is only found at places which are normally above the lake level but which are under water during a normal rainy season. When the lake is unusually low "*dothe la mcere silipezeka*" (salty soil is not found). What is normally lake bottom, and is only dry in abnormally dry years, does not yield salt.(³) All informants were agreed on this point. One informant said that at the Likangala, the Naisi, and the Domasi (rivers flowing into Lake Shirwa from the Zomba massif and north of the Palombe plain) there is no saline soil. In the districts around the mouths of these rivers, and also at the other side of the Palombe (to the S.E.) there is only *lenjere* weed. This statement was not corroborated.

The surface soil along with the dry grass and any vegetable matter lying on the surface is scraped up into heaps with a hoe,

scooped up in the hands, and put in a pot or basket and carried to the village. They say that the soil underneath the surface is not saline.

EXTRACTING THE BRINE—LIXIVIATION

1. *The Equipment Used.*—At the village the salt-maker has an earthenware pot similar to those used for water carrying. The average size is about 1ft. high, 1ft. at the widest part, and 6in. diameter at the mouth. In the bottom of this pot, which is used as a filter or strainer, a small hole is bored by twirling a fish spear (*momba*) or a hunting spear (*nthungo*) between the palms of the hands. Some of these pots which I examined had holes not more than ½in. in diameter. Another had an irregular hole about 3in. by 4in. If the hole is very small the saline soil is just poured into the pot. With a larger hole a small screw of dry grass is placed over the hole before putting in the soil. In the case of the large hole mentioned above the owner of the pot had made a smaller hole in an old piece of woven bamboo basket work and placed this over the hole in the pot as a temporary makeshift(4).

This pot is placed on a stand or " bridge " (*ulalo*) roughly made by erecting four small poles in the ground and fixing on top of these a platform made of other brushwood. In the middle of this platform a hole is left in which is fixed a *nkhata*—a ring of grass or banana leaves a little larger than a " tenikoit " ring. On this the pot stands. The bottom of the pot is some 18in. from the ground. Other salt-makers use three old pots filled with hard earth which they stand on their rims, on which to rest the straining pot (5).

Underneath the *nciringo* pot is placed a smaller pot with a wide mouth, into which the brine drips. An average-sized pot measured 8in. across the mouth and stood 8in. high. This type of pot has only a very slight curve at the neck, and the diameter of the rim and the body of the pot are about the same(6).

2. *The process of Lixiviation.*—The soil or ashes brought from the lakeside are placed in the pot on the stand. The bits of dry grass and other vegetable matter gathered along with the soil help to bind it together. My chief informant, Grace, said " *opanda maudzu samaukha bwino* " (without the grass it [i.e. the water] does not drip well. She also said that if there is no grass at the spot where the saline soil is collected, the salt-maker will find some to add to the soil. Water is now poured over the soil from a water pot by means of a *cikho* (gourd cup). The water quickly percolates into the smaller pot under the stand. The first potful of percolated water is very dirty, and is put back into the pot on the stand to be filtered. As the soil becomes saturated with water it settles down a little and acts as a filter. When the first lot of water is put through the soil for the third time it is usually considered clean enough. More water from the water pot is now poured on to

the earth and allowed to drip into the pot below. This process continues until the dripping water ceases to taste salty. The used soil is thrown on the ground near the lixiviation stand, where it hardens and forms quite a mound.

3. *The Boiling Down of the Brine.*—After lixiviation the brine is placed in a pot kept specially for the boiling down of the brine. It is similar to the *nciringo* pot used for lixiviation.

According to Grace, the pots used for boiling down the brine soon break, and there is a *mankhwala* (medicine) which is used for strengthening the pots. "*Amatenga mbiya ndi kukhula kunja kwace. Ndi mankhwala a dothe.*" (They take the pot and smear the outside of it. It is medicine made from earth.) Grace didn't know the name of the medicine nor how it is made. She herself does not use it. Jenet, another informant, said that she did not know anything about any medicine for strengthening the pots.

The cooking pots which I have seen held from 3 to 3½ galls. of water, but they were not more than half-filled with brine, and were put on the fire tilted some 30 degrees from the vertical. One pot of brine containing 13½ pints was put on the fire at 8 a.m., and the salt was ready to be removed at 12.30 p.m. This boiling of 13½ pints was reduced to just over three pints of salt. When the salt crystals begin to appear in the boiling brine they say "*maso a mcere aoneka*" (the eyes of the salt have appeared). The salt is taken from the pot with a *cibade* (gourd cup) (7) in a mushy state. At this stage it reminded me both in its colour and consistency of the slush caused by the melting of soiled snow which had previously been frozen. While the salt is being removed the pot is left on the fire. There is no brine left in the pot. The wet salt, on being removed from the pot, is placed in a *nsogoma* sieve(8).

4. *The Nyongo.*—The water remaining in the salt is allowed to drip through the sieve into a basin or pot. Actually, none of the salt-makers I watched used a proper *nsogoma* sieve. Instead, they used an old *nsengwa* (a shallow porridge basket made of bamboo basket work). According to Elliot, Grace's husband, no one in Kanthebwe village knows how to make the *nsogoma* sieve.

This water, which drips from the salt, is afterwards placed in a pot and left in the sun to evaporate. It is a clear brown in colour, not quite such a red-brown as vinegar. It is bitter (*kunyung'unya*) to the taste and is called *nyongo*. The term is also applied to the spleen and the gall bladder. It is also spoken of as *madzi a ululu* (poisonous water). According to Jenet, the *nyongo* is saved until the salt-making is finished for the time being—that is, until all the earth brought to the village has been used. By that time a good deal of evaporation has taken place and more salt is found at the bottom of the *nyongo*

pot. The *nyongo* is then thrown away and the salt is scraped out with the hand. This salt is bitter, and it is put in the *nsogoma* sieve and a little clean water is splashed over it. Then it is shaken gently from side to side until the water drips from the sieve. Then the salt is good.

Prohibitions and Sanctions Regulating Salt-making

There does not appear to be any prohibition regulating the seasons for salt-making. The season loosely corresponds to the dry season, as one would expect. Grace said "*ayamba atatema mapira ndikupalabe kufikira mvula*" (they begin after they have cut their millet and continue to scrape off [i.e. to collect the saline soil] until the rains. When the rain has come the salt is finished). Grace's husband interpreted the words "after they have cut their millet" as meaning, roughly the end of March. This, however, can hardly be correct, as the place where the saline soil is found is often still under water in March, and other informants agree that millet is cut in May. This is corroborated by my own observations near my own station at Namiwawa. The salt-making season may thus be said to start about May and finish at the first rains in late October or November.

Grace said that anyone may make salt, but in a later talk Grace's young married daughter told me that young women do not make salt, but only those who have been married a long time. I did not get to know any reason for this prohibition. Grace went on to say that if a salt-maker's husband is a libertine (*wolawalawa*([9])) "*atofa nawo ngati atereka pamene mwamuna ali kwa mkazi wina*" (she dies with it [i.e. the salt] if she puts the brine on the fire when her husband is with another woman).

If the husband should sleep with another woman the salt-maker will not use the salt she is making. This applies to all salt made from the store of saline earth then being used, whether dry salt already in the bag, brine on the fire, or soil not yet lixiviated. She will not even sell this salt, but will give it away. If she should eat the salt or profit by it, she would swell up and perhaps die. If the husband loved his wife he would come to a nearby village and send someone to tell his wife that he had offended or sinned against her (*kumcimwira*). If he did not love her she might hear from some well-wisher. If she should not hear she would just become ill and die. Another informant, Esinala, said: "Someone will come and say 'don't eat the salt,' and she would leave it and look for medicine" (*funa mankhwala*) ([10]).

In the case of polygamists, "*amalinda kufikira mwamuna abwere kwa mkazi wina*" (they wait until the husband returns from his visit to his other wife). Another informant said that

if a man has two wives, when he has slept with the one who makes salt, the following morning she will put her pot of salt on the fire. Then the husband will go to sleep with his other wife, and will return to the salt-maker next morning "*kuti mcere udziwa kuti pali mitala*" (in order that the salt shall know that there is a plurality of wives). If a man should be away from home at a time when he knows that his salt-making wife is about to make salt, he would not sleep with his other wife until he had first returned home and slept with his salt-making wife.

On one visit to the lakeside, Elliot, Grace's husband, showed me two samples of salt on a plate. One sample, made by Erubi Laimon, was of a medium brown colour, somewhat darker than milk chocolate. The other sample made by Grace was of a much lighter colour, a greyish-white, similar to unbleached linen. Elliot said in the presence of a number of people that both samples had been made in the same manner from the same saline soil collected from the same place. His statement was accepted by those present without demur, but I had no other way of checking the statement. Elliot said that in the case of the darker-coloured salt, made by Erubi, "*walozedwa mmisiri wace. Dulu silinacoka*" (the salt-maker [literally, 'skilled worker'] who made the salt has been bewitched [literally, 'has been pointed at with the finger']. The poison has not left the salt)(11). All agreed that this was so. When a salt-maker sees such dark-coloured salt she leaves her work for a few days and then tries again to see whether or not her bad luck has left her (*ngati tsoka lacoka*). If the salt is still of a bad colour she gets firewood and takes it, together with her remaining saline soil, to another salt-maker—in this case her friend Grace—and asks her to make the salt for her as she is bewitched. This bad luck is supposed to be caused by some enemy who is wishing her ill.

If the salt-maker herself has some sin on her conscience—perhaps, for example, she lied to, or about, her husband—and she puts the brine on the fire, she will only get a little salt, "*udi wa bi! cifukwa mtima sumakhala bwino iai*" (and it will be dark-coloured because her heart is not at rest, no).

Economic Factors in Salt-making.

1. *Competition*.—On numerous visits to Kanthebwe village between 1930 and 1940, though I had heard of salt-making, and occasionally seen women returning from the lake with baskets of saline soil, I had never actually seen salt made. This, although I had always stayed at the home of my chief informant, Grace, and within sight of the houses of two other salt-makers. I feel reasonably sure that, with the advent of imported salt, which is much finer and whiter than the local product, at a low price, the local industry, if not dying, had suffered an eclipse.

Common salt is made in large quantities on the East Coast of Africa, and is imported into Nyasaland from Portuguese East Africa and French Somaliland. The Nyasaland natives buy the salt chiefly from native stores run by Indian storekeepers. Owing to the war, however, the price of this imported salt has risen considerably—from 1½d. per lb. to 2½d. per lb.—and transport difficulties have become more acute, making it difficult to buy imported salt in outlying districts. This has led to a resuscitation of the local salt-making industry.

2. *Family Use.*—Salt is made primarily for the use of the salt-maker's own family, though, according to Elliot, all who make salt sell or barter some proportion of it. Salt is put in the *ndiwo* (meat, fish, vegetables, etc.) which is eaten with the maize meal porridge, but is not added to the porridge itself. Elliot and his son both told me on separate occasions that they had bought no salt this year (1941), suggesting that it had been their usual practice to buy some salt at any rate, if not their entire requirements. Elliot showed me a bag of salt weighing about 60 lbs. made by Grace. This visit was in September 1941. On my next visit in June 1942, this bag was nearly empty. My informant said that he and his wife and their four small children together with his married daughter and her husband and his married son and his wife—ten people in all—had used the salt. Some salt had also been given to friends, and some had been used for barter.

3. *Barter.*—Elliot said that he had also traded salt for cassava this year (1941), getting enough for the needs of his family. Maize, millet, cassava, etc., are bartered in this way. Heavy rains sometimes cause the Palombe to overflow its banks when the maize growing near the river is destroyed. At such times maize can always be bought for salt in villages further away from the river and lake. "The salt-makers take salt in a basket to the villages where there is much food, and barter there." They take a measure and measure the salt out in pennyworths, and the owners of the food also have the appropriate measures, or if it is cassava they heap it up in pennyworths (¹). Bartering also takes place at the native markets.

4. *Cash Sales.*—Much salt is sold either at the *makulo* (place for making salt—salt pit) where it is cheaper, or at the village of the salt-maker, but the maker also takes salt to the markets for the sale of native produce. Others take their salt to Napali, a place on the lakeside where fishermen put in to buy food. This "*doko*" (harbour) is the one nearest to Kanthebwe. The salt, which I have already mentioned which Jenet made from 13½ pints of brine and which was reduced to slightly over 3 pints, when measured out at current prices was worth a little over 5d. The same quantity of common salt from the store, roughly 4 lbs. in weight, would have cost 10d. at

current retail prices. Concerning the methods of selling salt some years ago an old Nyanja evangelist, Che Jameson Mitumba, whose home used to be by the lake, wrote me the following note:—

"*Mcere wa malonda unali kumangidwa mu ciondo. Ciondo ndi khungwa la ntengo limene akasema bwino lomwe kucotsa makungwa akunja kuti cipepeyale ndikukaviika pa matope kuti cikhale cakuda (kunika) ndi matope nagoma bwino bwino nayanika ndikuuma. Ndipo amapinda nasoka ndikuthilamo mcere natenga kukagulitsa popita kogulisa akatenga nsungwi kuwaza pena ziwili zamithutha ndikupana kuti atenge bwino. Pena akagulisa wosamasula ngati agulisa womasula anali kutenga namaloso (mbale) (cup) yimene akayesera pothira ncere coyamba akatapa cere kuthira munsengwa ndi kuthikhithiza namaloso pamwamba pace ndi kuyamba kuthira ncere atatha anali kuti nkhosolo (banyila) natapanso naonjezera. Mau omariza akanena malonda koma kugulana namuseka.*

Salt for sale was being tied up in a bark-cloth sack [13]. *Ciondo* is the bark of a tree which they adze carefully to take off the outer bark that it (the bark-cloth) might be thin and pliable, and they steep it in mud that it might be black (to dye) with the mud, and they strike it well and spread it out to dry. Then they fold it and sew it and pour the salt into it and take it to sell. Going to sell it they take a bamboo to split, or perhaps two whole ones, and fix the bags of salt between them that they might carry them well. Sometimes they will sell it without opening the bag (i.e. without measuring the salt out); if they sell it loose they used to take a *namaloso* measure [14] with which to measure when pouring out the salt. First they take a little salt to pour in the *nsengwa* basket in which they stand the measure, and they settle the measure down on the top of this salt and begin to pour the salt. When they had finished the buyer said "a little overweight," and the seller took a little more and added it. The final words (of the buyer) he was saying "it is trade, but to buy from each other you also laugh."

The last sentence is rather difficult, but Jameson explains it by saying that the buyer has no complaints, but a good-natured salesman would add a little more as a present that the customer might be glad.

5. *Custom Dues.*—If a shelter was built at the lakeside for the purpose of salt-making, custom had to be paid to the *mfumu ya dziko* (chief of the land), in this case Kanthebwe himself. My informant said: "*sacita tsopano koma kale*" (they don't do it nowadays, but long ago). Two informants agreed that one bag out of twenty would be given to the chief, but there does not appear to have been any hard and fast rule governing the proportion of salt due to the chief.

Chemical Analysis

The following is a report of an Agricultural Chemist on an average sample of lakeside salt, manufactured by my informant Grace at Kanthebwe village.

"The sample consists of small crystals, is of a greyish brown colour, only a little darker than the common grade of salt. It was damp and the crystals clung together.

Loss on drying at 120°C.	8·9%
Matter insoluble in water, mainly sand ...	0·5%
Total chlorine (Cl.)	53·1%
Equivalent to sodium chloride	87·5%

Qualitative test shows:

Sulphates: A small amount, more than a trace.

Oxide of Iron, Alumina: Negative.

Lime: A small amount, more than a trace.

Magnesia: A trace.

Heavy metals: A trace only.

In its present condition it could be used for culinary purposes, but a further purification to remove sand is desirable."

NOTES.

(1) See "Handbook of Nyasaland," compiled by S. S. Murray, 1932 Edition, p. 6.

(2) *Njeza* is a kind of water grass like a bullrush. It is found floating in clumps on Lake Shirwa. When the seed is ripe in November and December it is carried many miles by the wind.

(3) They say "*dothe la mcere ndilo la pa mtunda—la dongo.*" That is, salt yielding soil is of the dry land—of clay (not sandy).

(4) The generic term for pots is *mbiya*, and this type of pot when used for water carrying is called *mtsuko*, but when used for extracting brine it is called *nciringo, or a cezeko* (strainer) or a *cicezo* (see Scott and Hetherwick: Dictionary of the Nyanja Language, p. 47). I have never heard this latter term used, but when I mentioned it to one informant he agreed that this is "true Chinyanja" and said it means the same as *cezeko*.

(5) This contrivance, whether in the form of a stand or merely consisting of old pots or stones is called the *ulalo* or *ulalo wa cezeko* (bridge or bridge of the strainer) or merely the *cezeko* (the strainer). This latter term deriving from *kuceza*=to strain, is, however, more usually applied to denote the lixiviating equipment as a whole.

(6) This type of pot is used for cooking *ndiwo* (meat, fish, sauce, etc.) when it is called a *mphika* (*kuphika*=to cook). When used for salt-making it is generally called the *cicero* (the thing into which it strains).

(7) The *cikho* previously mentioned is a drinking cup made from a gourd with a long elongation which forms the handle. A small hole is cut in the rounded part to form the mouth of the cup. The term *cibade* is used for any piece of the hard rind of a gourd and also for the half of the gourd cut for a cup.

(8) The *nsogoma* is a conical three-sided sieve made of bamboo basket work. The strips of bamboo used are about a quarter of an inch in width. A *nsogoma* which a craftsman made for me measures five inches from the apex to the nearest point on the sides and six-and-a-half inches from the apex to the corners. About two inches up the sieve he drew a circle with charcoal. He said this was their method of measuring a pennyworth of salt.

(9) *Kulawa*=to taste. Generally food or beer. *Wolawalawa* therefore means one who frequently tastes, and by analogy one who doesn't settle down in any one village but lives first here, now there, and finally the word comes to mean one who lives with a number of women. One old man said to me, the old men say to a libertine "*bwanji muli kulawa mkazi ngati cinangwa?*" (why are you tasting a woman as if she were cassava?).

(10) There appears to be some dangerous quality about salt and fire. During menstruation a woman will call a friend or one of her daughters who has not yet menstruated to put the salt in the relish (*ndiwo*). She believes that if she puts the salt in the pot during menstruation her husband and children would be taken ill if they ate the relish. They would swell up, or their faces would lose their healthy look, or their teeth would become loose and they might even die. Fire, too, is dangerous. Pot-makers say that it is necessary after firing pots to wash the eyes in water in which medicine has been steeped. Otherwise the fire would enter their eyes and they would become ill and die. In the case of pot-making, too, it is necessary for the husband to abstain from copulation the night before the pot-maker fires her pots. Although the saline soil is lixiviated on the same day as the resulting brine is boiled down, it is noteworthy that it is the putting of the brine on the fire which is stressed when speaking of these sanctions.

(11) *Dulu* (or *ndulu*) means "the spleen; the gall of the crocodile, used with other ingredients to make poison" (Scott and Hetherwick: Dictionary of the Nyanja Language, 1929, p. 375) Elliott says the *dulu* of the salt is the "*ukali wace*" (its fierceness or bitterness).

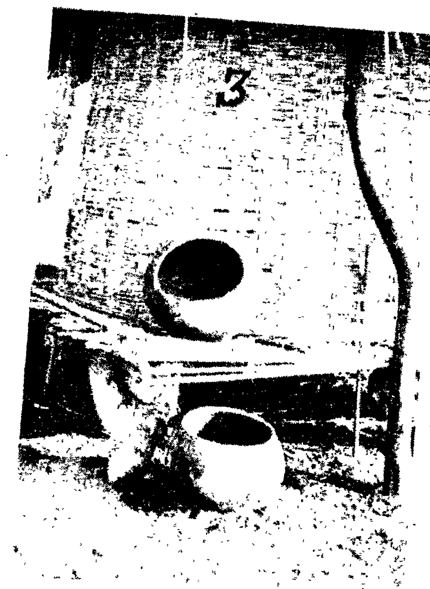
(12) Usually the measure is a *cibade* (gourd). Jenet's *cibade* was 2½ inches in diameter and about one inch deep at the centre. This she placed in a small basin and poured salt in until the *cibade* was completely covered. The quantity was a pennyworth.

(13) For *ciondo* see Scott and Hetherwick: Dictionary of the Nyanja Language, p. 92, under *ciwondo*, cuondo. The bag itself is called a *mphinda*.

(14) *Namaloso*. I cannot trace this word in the dictionaries.

1. Pouring water from a water pot on to the saline soil in the *nciringo* pot on the *ulalo wa cezeko* (straining stand).

2. Lixiviation plant. Note the mound of used soil behind the *nciringo* pot.



3. *Ndulu* is left in pots in the sun to evaporate.

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A PRELIMINARY REPORT OF AN INVESTIGATION OF SPOKEN ENGLISH IN SOUTH AFRICA

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. *Read 3rd July, 1944.*

The investigation of spoken English in South Africa, of which this is a very preliminary report, was undertaken partly for the purpose of producing a Dialect Atlas of South Africa similar in scope to those planned for North America, (1) and partly for the purpose of discovering what the actual speech habits of South Africans are. And at the beginning I wish to acknowledge gratefully the assistance given by the National Research Council and Board.

In previous publications it has in the first place been assumed, quite unjustifiably it seems, that pronunciations regarded as standard in England are automatically the " best " and the only " correct " pronunciations in South Africa, and in the second place the problems involved have been over-simplified.

Mr. Swanepoel in his work (2) is concerned mainly with listing the ways in which " the Afrikander's pronunciation [of English] departs from the accepted standard," (3) and his attitude may be illustrated by the following words taken from his preface:

> " If the need for reform is felt in a unilingual country like Australia, it stands to reason that bilingual South Africa will have to double her efforts in trying to preserve purity of pronunciation." (4)

Professor Hopwood (5) deals with the pronunciation of English-speaking as well as Afrikaans-speaking South Africans. His attitude may be illustrated by his quoting from Jespersen: " ' Mankind Linguistic,' p. 49. ' . . . I have pointed out that the language used by the child is determined far more by that of its playfellows than by that of its parents ' " (6) (or his English teachers, we might add; for the child listens to the speech of his playfellows, and that of other teachers, for a much bigger proportion of his day than to the speech of his teacher of English), and then going on to say:

> ". . . it is safe to predict that, unless the results of this investigation are seriously considered and steps taken by means of exercises on each point in schools to counteract these characteristics and tendencies of SAEP [South African English Pronunciation], the next generation of South African born E. speakers will not only use these characteristics more definitely than at present but will have converted many of the tendencies into characteristics."(7)

I shall say more later on these questions of "correctness" and the counteraction of "incorrect" South African pronunciations.

I said that in the second place previous publications had over-simplified the problems. Swanepoel, for example, says:

> "In Afrikaans this vowel has a very strong nasal tendency, and consequently the Afrikander often nasalises the English vowel."(8)

The question of course is: what does he mean by "the Afrikander"? Does he mean all Afrikanders? And, if not, which ones? Similarly, in most comments on the pronunciation of English-speaking South Africans there is the same tendency to assume that there is one South African English pronunciation, that it consists of a certain number of pronunciations different from those of Standard English, and that by the nature of things those pronunciations, in differing, are inferior. The implication is often that all English-speaking South Africans use the same variant pronunciations. A moment's thought is sufficient to convince people that such generalisations do not represent the facts. The question which English-speaking South Africans use one of alternative pronunciations, and which use the other, is, of course, a statistical question; and the problem cannot be solved any other way. Professor Hopwood mentions figures; but these appear to be only a rough estimate, and no statistical evidence is quoted to support them. He says:

> "In the following index of SAEP characteristics, the more definite ones are marked by stars. The changes are represented in phonetic symbols most nearly approaching an average pronunciation of those who exhibit these tendencies. . . . By 'average pronunciation' is meant what is common to the speech of any five boys in their 'teens, chosen at random from any Primary School in the Union. Three at least will exhibit the starred peculiarities individually, and they will among them all exhibit the whole series of these characteristics. . . . In Secondary Schools the story is much the same, the difference in variation of pronunciation being only a matter of degree in tendency."(9)

The purpose of this investigation was in part to establish more accurately, by statistical methods, the actual spread of variant pronunciations of English in South Africa. The investigation has been limited so far to schools in the Transvaal, and limited to English-medium schools, mostly high schools, some for boys only, some for girls only, and some mixed. In each school pupils of two age groups, with a difference of approxi-

mately three years between them, have been tested. On an average about twelve pupils from each class were taken. The only selection exercised was that children whose home language was English were picked out. Some attempt was made to learn something of the linguistic background of each, information being sought concerning the suburb in which the child lived, concerning the parent's occupation, parents' home language and birthplace, "correction" of speech in school, if any, the taking of elocution or music lessons, and so on.

This means that so far no systematic attempt has been made to test the speech of children of pre-school age, of university students or of any people above the age of 18 or 19. But sufficient evidence is available from what has been done to show that the pronunciation of English amongst English-speaking South Africans varies not only in regional groups, but in age groups, class groups and sex groups.

I want next to present some of the evidence for this grouping, with a few comments by way of interpretation. And in order to keep this report as brief as possible I propose to discuss the pronunciation of some half a dozen keywords only.

I. Class Groups.

To illustrate the difference between the pronunciations of different class groups, I shall quote some of the figures obtained from tests at two Johannesburg girls' schools, and refer to the two schools as H and L, H being used of the school at which the pupils are drawn for the most part from a higher economic group—as I think would be admitted by all except perhaps those parents who send their daughters to the other school, which we will label L. L, whose pupils come from the relatively lower economic group, is a school which, nevertheless, is situated in a good, upper middle-class district, and is a school at which some attention is paid to the pronunciation of English by the pupils. At H the teachers are often appointed from England, at L some are South African born I shall take from each school representative groups of senior pupils of about the same age.

In the case of the word *out* the standard pronunciation in England is generally taken to be [aut], though the first element of the diphthong may vary permissibly between cardinal vowels 4 and 5. In South Africa the most frequent non-standard pronunciation is one in which the first element of the diphthong is raised—to a high [a], to [æ] or even to cardinal vowel 3. At school H 63 per cent. said [ɑut], and the rest [aut]; i.e. there were *no* non-standard pronunciations in which the first element was raised. But at school L 20 per cent. said [æut], and another 13 per cent. used a high [a]; the remaining 67 per cent. used an accepted standard pronunciation. That is to say, even at a good upper middle-

class school where attention is paid to pronunciation a total of 33 per cent. used a non-standard pronunciation.

Other results of the tests at these two schools may be summarised as follows:

	Word	Standard pronunciation	Non-standard pronunciations (with high first element)	Non-standard pronunciations (with still higher first element)
	boy	bɔi		boi
H	... ...	67%	33%	
L	... ...	23	23	54
	gate	geit	g it (with first element lower and further back)	
H	... ...	91	9	
L	.. ...	64	36	
			(with higher vowel)	(with vowel near that in *on*)
	can't	kɑ:nt		
H	....	58	42	
L	... ...	30	50	20
	swim	swIm	swəm (with vowel lower and further back)	
H	... ...	88	12	
L	... ...	40	60	

These differences seem to be based on the feeling among the higher economic groups that the only certainty about the pronunciation of English is that the standard pronunciation of England is at least traditionally respectable, and that it alone can be relied upon to produce the right social effect and mark off the speaker as one belonging to a privileged group —a group with close and recent ties with " home," either through the accident of birth or the privilege of education or travel overseas, where everything is automatically superior to anything " colonial." That is to say, it is partly a matter of snobbery and of playing safe, for South African English pronunciations have no tradition behind them, and their status is still uncertain. Indeed, as we have seen, authorities have in the past condemned them.

Although the pupil's speech may be influenced more by that of her schoolfellows and teachers than by that of her parents or teacher of English, at a school such as H the pupil finds herself among a group of schoolfellows already disposed to regard the standard English of England not only as the only " correct " pronunciation but as one highly desirable socially; and she finds herself exposed to the same standard English of England from teachers of other subjects than English, since most of the teachers are specially imported from England.

This attitude towards South African pronunciations of English is reinforced by the prejudices of recently arrived English people. The reactions of these people to South African

pronunciations are like the reactions of most people who are set in their ways, as most of us are linguistically, to anything new: they tend to dislike what they are unfamiliar with, call it "inferior, ugly, unpleasant, harsh" (or label it by any other equally vague emotive term of disapproval—which they find impossible to define when challenged) because they are unaccustomed to it—in just the same unscientific way as South Africans, for example, talk of an "ugly, unpleasant, harsh" American accent.

It is difficult to imagine any reason why one pronunciation of itself should be better than any other. The only standard of measurement of good or bad seems to be intelligibility. And "we aint" seems to be just as intelligible as "we aren't" or "we are not." The reasons why one pronunciation is in practice preferred to another are usually social reasons. I have in fact heard a man deplore the North of England pronunciation of *man* as vulgar, but describe the German pronunciation of *mann*, with the same vowel sound, as having a fine patrician ring about it. And the only reasons for teaching children to say one thing rather than another are social reasons. When "correctness" is a matter of social discrimination the child needs to be warned; and as long as there is a feeling against a particular pronunciation the pupils should be taught the "correct" pronunciation as a protection against the prejudice which might be roused against them. An opinion of the "correctness" of a pronunciation seems therefore to be no more than an estimate of its social effect.

What is correct for the individual is what is usual in his group. The child pays a social penalty in not conforming, and suffers ridicule if for example he uses South African pronunciations in a group of exclusively standard English-speaking children, *and* vice versa. In practice, of course, the individual tends to adapt his speech, consciously or unconsciously, to that of the group in which he finds himself, unless he deliberately tries to mark himself off as different.

A third reason for the belief that South African pronunciations of English are inferior is that certain pronunciations common in South Africa remind newly arrived English people of class or regional dialects in England. The pronunciation [gəit] for *gate*, for example, suggests to English ears a Cockney pronunciation, although it is almost certainly an example of the influence of Afrikaans on English and not of Cockney at all. That is to say, our likes and dislikes of particular ways of speaking often depend on the associations they call up, consciously or otherwise.

This deliberate attempt to preserve the standard English of England as a standard in South Africa is an attempt to knock the individuality out of South African English. And it is perhaps not too much to say that the attitude created

towards what is felt to be South African has been in part responsible for the almost complete absence of any literature of any quality in English in South Africa.

One might add that the South African Broadcasting Corporation, in appointing as announcers men who are English born or who have acquired a pronunciation that is very near the standard English of England, helps to perpetuate this superior attitude adopted towards South African pronunciations of English.

It is, of course, in fact impossible for the S.A.B.C. and the English-born teachers to remove completely *all* traces of South African pronunciations from the speech of South African born pupils. Certain schools concentrate on those characteristic pronunciations which are presumably the most obvious to English-born teachers, and do succeed in inducing their pupils to acquire the standard English sounds on which they concentrate; for example, in school H 88 per cent. of the pupils tested gave the word *swim* the standard English vowel. But a good number ot pronunciations which are characteristically South African are apparently not obvious to English-born teachers, and because they are less remarked are less subject to "correction" by them. These, for instance, the glottal stop before words beginning with a vowel, continue almost unchecked; so, for example, even at school H in the phrase *there isn't* 46 per cent. of those tested introduced the glottal stop before the vowel of *isn't* and did not pronounce the *r* of *there*.

In other words those who strive to preserve the standard English of England as the standard for South Africa are fighting a losing battle. After all, whenever groups of people speaking the same language become separated from one another, whether the barrier is 6,000 miles of ocean or the equally effective barrier of class, the speech of the two groups will develop in different but not necessarily "better" or "worse" ways. If the members of one group become unfamiliar with the speech of a second and profess to dislike it, they have a very good reason for not adopting it themselves, but a very poor reason for trying to compel everyone else to adopt their way of speech. There is no good reason why South Africans should be ashamed of their speech, or believe it inferior to any other kind of English.

It would, of course, be unfortunate if the varieties of English spoken in Great Britain, the United States of America, South Africa, Australia, New Zealand and Canada developed unchecked and diverged to such an extent that English lost its universality. Some standardising influence is necessary. But it is supplied—very largely these days by such things as broadcasting, sound films, mass education, travel and the printed word.

I have given a good deal of space to a discussion of the English of class groups in South Africa because an understanding of what has happened in the other three groups I mentioned (sex, age and regional ones) depends upon it.

II. Sex Groups.

Statistics confirm the suspicion that girls as a whole pay more attention to "correct" speech than boys do, i.e. the speech of girls is, on the whole, nearer to standard English than boys' is. In fact, the attitude of the boys seems to be that it is effeminate to speak "correctly." The following figures for similar age groups in the boys' and girls' high schools in the same Transvaal town illustrate the differences:

Word	Standard pronunciation	Non-standard pronunciations		
gate	geit	gəit (with first element lower and further back)		
Girls ...	62%	38%		
Boys ...	0	100		
can't	kɑ:nt	(with higher vowel)	(with vowel near that in *on*)	
Girls ...	62	38	0	
Boys ..	0	53	47	
out	aut	(with high a)	ɐut (with still higher first element)	
Girls ...	85	15	0	
Boys ...	25	17	58	
boy	bɔɪ	(with higher first element)	boɪ (still higher)	(diphthong same as Afrik. *gooi*)
Girls ...	15	38	47	0
Boys ..	0	16	42	42

The actual figures for other comparable groups of boys and girls would not be the same as those above, of course, for they would depend on the class, regional and age groups to which they belonged. But those I have quoted are characteristic in that the results obtained so far confirm that the figures for girls and boys all differ in the same way; the girls of comparable groups always show a higher percentage of speakers who are nearer to standard English than the boys.

The same difference between the speech of boys and girls was noticeable in mixed schools, and even in the same family. For example, in one class at a Reef high school for the word *gate* nine girls said [geit] and six said [gəit], while all the boys tested, eleven in all, said [gəit]. At another Reef high school three pairs of brothers and sisters were among those tested, and in each of the pairs the pronunciation of the sister was

nearer to standard English than that of her brother, e g one of the girls used a standard English pronunciation for *gate*, *boy*, *listen*, *can t* and no glottal stops before the words beginning with vowels which occurred in the test phrases, whereas her brother used non-standard pronunciations in each case

In other words the girls seem to be more socially conscious than the boys, or a sense of propriety and decorum is developed in them more easily, or at least at an earlier age (See next section)

III Age Groups

It was noticeable that in almost all cases the speech of the older group was nearer to Standard English than that of the younger group at the same school That is to say that as they grow older, boys as well as girls become increasingly aware of the class distinctions which different pronunciations suggest Even though the boys never show quite the same zest for " correctness " there does come a time which seems to correspond roughly with that at which they begin to wash behind their ears when they realise the social significance of pronunciation The following figures will illustrate the point briefly

Girls High Schools in Johannesburg	Word	Percentage in younger group with standard pronunciation	Percentage in older group with standard pronunciation
A	*gate*	12	64
B		79	92
Boys High Schools in Johannesburg			
C		29	59
D		18	40
Reef High School			
E		0	30
Transvaal High School for Girls			
F		9	62

IV Regional Groups

Figures here reveal what would be expected, that on the whole children in a large English-speaking centre such as Johannesburg adopt a pronunciation nearer to standard English than do children of similar groups in smaller Transvaal centres. That is to say, the percentage of boys in a given group at a boys' high school in Johannesburg who use standard English or near-standard English pronunciations will be higher than in a similar group of the same age and class in a boys' high school in a smaller town although the percentage of boys at a boys' high school in Johannesburg who use standard English may, for example, be lower than that of girls in certain high schools in smaller towns

But not enough work has yet been done to allow one to say with certainty any more than that there are regional differences. Just what the differences are throughout the Transvaal, and the Union as a whole, and where the limits of the differences are to be found, are questions to which only further investigation can supply answers.

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EVENING DISCOURSE.

SOME PROBLEMS OF INTERPLANETARY TRAVEL

BY

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Read 4th July, 1944.

1. For many years the discussion of travel through interplanetary space has been the monopoly of the writer of fantastic fiction. Jules Verne, H. G. Wells, E. R. Burroughs, to name but a few, have described for us the experiences of the first men to make an inter-planetary voyage. Unfortunately, none of these writers has provided us with a workable blue-print of the space-ship whereby this exciting voyage has been accomplished.

Verne suggested projecting his travellers on their way to the moon by means of an enormous cannon, whose barrel was to be 900 feet long. By means of a charge of 200 tons of explosive the projectile, carrying three intrepid explorers, would be accelerated in a distance of some 700 feet to a velocity of just over 36,000 feet per second, in order to escape from the gravitational pull of the Earth. To take up the shock of the initial acceleration the travellers were to rest on a platform floating on three feet of water, thus effectively increasing the length of the barrel by three feet. According to Verne, the effect of the explosion was to render the three men unconscious for a short time.

Unfortunately for an otherwise well-planned attempt, this latter fortunate circumstance must be regarded as extremely improbable. In order to accelerate to the required velocity in the length of the gun barrel, the projectile, with everything it contained, would require an average acceleration of rather more than 1,000,000 feet per second, or something like 30,000 times the acceleration due to gravity at the earth's surface. Each traveller would therefore be acted on by a force some 30,000 times his own weight, which would mean, for a man of average weight, a force of the order of 3,000 tons weight. Few men could be expected to recover after a brief spell of unconsciousness after having been subjected to the compression of a weight of 3,000 tons.

Wells evaded the difficulty by postulating the existence of a substance not subject to gravitation, in spite of the fact that there are not even theoretical reasons for believing such a substance to exist, while Burroughs uses some mystic method which is not even described. The fictionist therefore gives us no guidance in

our search for practical possibilities, and it becomes necessary for science to do what it can to make this a respectable subject. Since of recent years there has been a great deal of serious scientific thought given to the possibility of travel in space, I have thought that a discussion of some of the problems that have to be met might not come amiss.

2. In the limits laid down by our present knowledge, theoretical or practical, limits that must determine the bounds of all scientific discussion, what are the possibilities in this connection? Our major problem is to find some method of propelling a vehicle in the emptiness of that space which lies between the planets, or alternatively, of giving a projectile a very large velocity without introducing such enormous accelerations as to make it impossible for men to travel in the projectile. The only principle known is that of *reaction*, in the form of a rocket motor, of which one has heard a great deal lately.

In the first place, a rocket is more effective in a vacuum than in air, while by a suitable choice of propellant, it is possible to make the acceleration as small, or as large, as is desired.

The reaction principle is a familiar one, based on the Third Law of Motion enunciated by Newton: To every action there is an equal and opposite reaction. The precise application of this Law can be seen by considering, for example, a man on a perfectly smooth horizontal surface. As long as the surface is perfectly smooth it would be impossible for him to start moving forward by any ordinary process such as walking. In order to develop a forward velocity, however, he could remove a shoe and project this backward. His hand exerts a force on the shoe, which is therefore associated with an equal and opposite force exerted by the shoe on his hand. This force of reaction will cause him to move.

In a rocket the same principle is utilised. By means of some process of combustion a mass of gas inside the rocket chamber is heated to a high temperature, and thus gains high pressure. This gas streams with considerable velocity through an orifice from the chamber, under the influence of a resultant thrust in this direction on the escaping gas. By the Third Law this gas exerts an equal and opposite thrust on the gas still in the chamber and hence on the body of the rocket thus propelling the rocket in a direction opposite to that in which the gas is ejected.

Since the velocity of escape depends on the difference between the pressures within the rocket chamber and in the space outside, this velocity is greater if the external pressure is less, and is greatest in the case of a zero external pressure. Hence the rocket functions even more efficiently in vacuum than in air.

The theory of the rocket is fairly simple and well known. If we suppose that in each second a mass m of gas is ejected with speed v relative to the body of the rocket, the total mass of which.

is M at the instant concerned, then during that second the rocket will gain a forward velocity dV given by the equation of Conservation of Momentum, $M{\cdot}dV = m{\cdot}v$, except in so far as the gain in velocity is reduced by the action of gravity and air-resistance.

Our object must be to obtain a large increase dV in the velocity of the rocket in each second, and it is clear from this equation that we will need, in general, a large m and a large v, that is, a large mass of gas ejected with high speed.

A simple calculation shows that the rate at which the expanding gases do work is $\frac{1}{2}\, m\, v^2$, but of this work only a portion is in general expended on the rocket, the remainder being expended in giving the escaping gas a high, and useless, velocity. The rate at which the rocket gains energy either in the form of increased velocity or of work done in overcoming gravity and air-resistance can be shown to be $M\ V\ v$, so that the fraction of the total energy gained by the rocket, which we can regard as the efficiency of the rocket, is $2\ V/v$. Hence the efficiency of the rocket is proportional to its speed in relation to the speed of ejection of the gas. If the rocket is moving at one-half of the speed of ejection, all of the energy of the expanding gas is transmitted to the body of the rocket, while for higher speeds the efficiency in this sense becomes greater than unity. This unusual result is due to the fact that the rocket motor exerts a constant thrust $m\ v$ at all speeds, so that the power exerted on the rocket increases directly with the speed. In most motors the power developed is constant and hence the thrust decreases with the speed. In order to specify the rating of a rocket motor, therefore, it is meaningless to specify the horse-power, since this varies directly as the speed. A much more meaningful specification would be the average thrust in pounds weight, or alternatively, the rate of ejection of mass and the velocity of ejection from which, as we have seen, the thrust can be calculated.

The total rate of evolution of kinetic energy, $\frac{1}{2}\ m\ v^2$, is ultimately determined by the rate at which energy is liberated inside the rocket chamber by the combustion of the rocket fuel. Experiments have shown, particularly in the hands of R. H. Goddard, that the rocket motor in itself possesses an efficiency which in most cases is very low. In other words, of the energy of combustion, only a certain proportion is available in the form of kinetic energy of the expanding gas. Goddard has shown that this purely mechanical efficiency of the rocket motor, as distinct from the efficiency of the rocket itself previously discussed, increases with the speed of ejection v of the exhaust gas, ranging from something like two per cent. for exhaust velocities of about 1,000 feet per second, as in ordinary ship rockets, to about 60 per cent. in the case of exhaust velocities around 8,000 feet per second. This latter figure exceeds the efficiency normally attained in the best internal combustion motor.

To give some idea of the sort of problem met with in the design of rockets let us consider a rocket in which the fuel is petrol which is burnt together with oxygen under pressure. In the combusition of petrol and oxygen the heat liberated for each gram of the mixture is of the order of 2,400 calories, or approximately 10^{11} ergs. Assuming an efficiency for the rocket motor of 70 per cent., the kinetic energy carried with each gram of the exhaust gases will amount to $7 \,.\, 10^{10}$ ergs. Hence the exhaust velocity v will be given in centimetres per second by

$$v^2/2 = 7 \,.\, 10^{10}$$

whence we derive an exhaust velocity of about 3,750 metres per second, or approximately 12,000 feet per second. If the rocket is propelled by exhaust gases produced by the combustion of petrol in oxygen we should therefore be able to obtain exhaust velocities of this order.

If for simplicity we assume the rocket to accelerate from rest in free space so that the effect of gravity and of air resistance can be neglected it is easy to show that the final velocity V is given by

$$V = v \log_e M_0/M_1$$

where v is as before the relative velocity of ejection.

M_0 is the original total mass of the system, and

M_1 the final mass.

As an illustration let us assume that nine tons of fuel are burned, giving an ejection velocity of 12,000 feet per second; the final mass of the rocket being one ton. Then we can show from the above relation that the final velocity of the one ton mass will be over five miles per second, and it can also be shown that in reaching this velocity the rocket will move through a total distance of over one thousand miles if we allow for a maximum acceleration of four times that due to gravity. The time taken will be about nine minutes. Since such an acceleration is not beyond the limit that can be borne by the human frame the attainment of such a velocity in a rocket carrying human passengers is therefore within the limit of possible attainment.

3. If the rocket is to move vertically upward under gravity (acceleration g) and air-resistance R per unit mass, the acceleration of the rocket dV/dt can be shown at any instant to be given by the equation

$$dV/dt = m \,.\, v/M - g - R$$

where m is the mass ejected per second with velocity v relative to the body of the rocket, as before,

M the mass of the rocket at the given instant

For any given values of m, v and M, and for any known law of air-resistance R, this equation must be integrated numerically. The theory of the rocket can then be regarded as complete.

Our problem then becomes to gain as large a value of the final velocity V for a given expenditure of energy as possible, and

it can be shown that the solution of this problem is directly linked with the problem of obtaining as large a value of the velocity of ejection v as possible.

A simple calculation shows that in order to produce a given final velocity in a final mass M_1, we require an initial mass of propellant which is roughly proportional to $e^{1/v}$. By increasing the velocity of ejection from 12,000 to 24,000 feet per second the required mass of propellant for any given final velocity is reduced by a factor of about 4. An increase of velocity of ejection by a factor of 2 requires roughly a four-fold increase in the energy emitted per unit mass of the propellant, so that our problem reduces to that of obtaining a propellant which will provide us with the greatest possible quantity of energy per unit mass.

4. So far the source of energy used in rocket experiments has been the heat energy released by the combustion of some convenient fuel. In his early experiments Goddard used a number of explosives of which the most satisfactory was a special shotgun powder which on combustion yielded 1,240 calories per gram, i.e., a total of about 5×10^{10} ergs per gram. With this fuel he obtained exhaust velocities very near to 8,000 feet per second.

Other reactions, however, are known to yield considerably more energy per unit mass. Thus in the combustion of carbon in oxygen 2,140 calories are released for each gram of the reacting substances, while the combustion of the hydro-carbons such as petrol is a still more fruitful source of energy. The combustion of hydrogen in oxygen yields some 3,800 calories, or about 1.6×10^{11} ergs per gram. Esnault-Pelterie, one of the pioneers in this field, as in aeronautics, has estimated that the maximum attainable velocity of ejection for any rocket motor based on chemical action is of the order of 30,000 feet per second, but it seems doubtful whether this velocity can be obtained on a large rocket. The practical limit would seem to be well below this figure, and at present the practical limit seems to be very near to 12,000 feet per second.

5. Assuming, then, that by chemical means it is possible to attain a velocity of ejection of 12,000 feet per second, would it be possible to build a rocket capable of inter-planetary flight? What forces must be overcome in travelling to the moon or to one of the planets?

The process can be divided into three stages:

(i) The rocket gains velocity immediately after leaving the surface of the earth. Work is done by the fuel in increasing the velocity, in overcoming the weight of the rocket and in overcoming the resistance of the air. This latter factor can be very considerably reduced by suitable streamlining and by starting from a great height, where air-resistance is considerably less for a given speed than at sea-level.

(ii) After a fairly short time, of the order of minutes, the rocket has reached a point well beyond the atmosphere and has gained a sufficiently large velocity. The fuel supply is cut off and the rocket proceeds to move under the earth's gravitation only, its speed being slowly reduced as it does so. This continues until it enters the region in which the attraction of the planet to which it is voyaging becomes greater than that of the earth or the sun.

(iii) The rocket is then drawn with gradually increasing speed towards the planet. The energy gained in this attraction must be dissipated before landing, either by means of the expulsion of further gas in such a direction as to oppose the downward motion towards the surface of the planet, or possibly by utilising the atmospheric resistance of the planet, assuming that this possesses such an atmosphere.

During these three stages, therefore, the rocket motor must provide sufficient energy to overcome the attraction of the earth, the sun and the planet, except in the case where the planet has sufficient atmosphere to make it unnecessary to use the rocket motor for a landing at sufficiently low speed. It is, perhaps, better not to make any assumptions in this respect at the present stage.

We can then calculate the total energy required to transport one gram of material from the earth to any one of the other members of the solar system, taking these factors into account, but neglecting air resistance, with the results given in Table 1.

TABLE I.

ENERGY REQUIRED PER GRAM TO REACH THE VARIOUS MEMBERS OF THE SOLAR SYSTEM.

Body	Minimum Distance from Earth (Miles).	Energy per gram $\times 10^{12}$ ergs.
Moon	240,000	0·64
Mars	45,000,000	2·27
Venus	25,000,000	2·90
Neptune	2,700,000,000	7·06
Uranus	1,700,000,000	7·5
Mercury	56,000,000	7·6
Saturn	790,000,000	11·7
Jupiter	390,000,000	22·9

In this Table the bodies have been given in the order of the energy required per gram. Thus it is seen that it is easier to reach Neptune than Jupiter if we neglect the possibility of dissipating the energy of free fall to the planet by atmospheric resistance. If this possibility can be depended on the picture is

very considerably changed and it then becomes true that the most difficult body to reach is Mercury and the easiest not even the Moon, but Venus.

At the present stage, then, it would be best to aim for a flight to the Moon, as demanding less time and energy than the corresponding voyage to any other body in the system. Assume that it is intended to take a rocket ship to the Moon and return to the Earth after landing on our satellite. Assume, for example, that the final mass which is to land on the earth on the return is to be one ton.

If all energy acquired under gravity is to be destroyed by means of the rocket motor and if the velocity of ejection is taken to be 12,000 feet per second we find that the total mass of propellant required amounts to 1,600 tons. Under these circumstances, therefore, it would be impossible, at the present stage, to land a rocket on the Moon and then return to the Earth.

If the velocity of ejection can be doubled the mass of propellant required will be reduced to something of the order of fifty tons, which is probably a practical possibility.

We might add that if the energy of gravity can be dissipated in the Earth's atmosphere on the return journey an initial mass of about 80 tons of fuel would be required for an exhaust velocity of 12,000 feet per second.

An alternative which would make the problem considerably simpler would be to propel the space ship so as to describe an orbit about the moon and then return to the earth under the influence of the moon's attraction in what is known as an "Ejection Orbit." Such orbits have been studied by various mathematical astronomers, particularly the Copenhagen School, and provide a view of the unknown rear face of the Moon, at the expenditure of a maximum of some 20 tons of fuel. Under the circumstances, therefore, such a flight would seem to be a distinct possibility at the present stage of development of rocket flight.

To summarise our conclusions thus far, therefore:

(i) At present it is possible to make a flight in an ejection orbit about the Moon to return to the Earth without landing on the satellite.

(ii) A landing may possibly be carried out with reasonable hopes of returning to the Earth only if the energy gained on the return to Earth can be dissipated in the atmosphere.

(iii) If the velocity of ejection can be considerably increased, travel to the planets is a possibility.

6. One feels that the above possibility is a very poor return for a great deal of activity and the question arises whether there exists any likelihood of an improvement in the position in the near future. Fortunately, it does at present seem likely that

developments may shortly take place which may well change the whole aspect of the problem.

We have seen that chemical sources of energy are not likely to lead to any appreciable increase in the ejection velocity attainable. There exists, however, a further possible source of energy, of a totally different order of magnitude, namely the physical energy which is locked in the interior of the atom.

A gram of radium, for example, emits during the period of its existence a total of more than 10^{17} ergs of energy, several thousand times more than the energy needed to lift that mass to Jupiter. Unfortunately, however, this energy is liberated very slowly over a total period of several thousand years, so that radium does not provide us with a possible rocket fuel, where we require a large amount of energy to be made available in a comparatively short time, of the order of some minutes.

In the last few years before the outbreak of the war, however, research in the new science of nuclear physics has pointed to the possibility of controlling the process of breaking up of atoms which occurs naturally in radium, but also can be made to take place under certain laboratory conditions. One such atom-splitting reaction in particular takes place in the case of the atom of one of the varieties of uranium, the so-called U^{235}. This atom, which has the chemical properties of uranium, is slightly less massive than the common isotope of that element, having an atomic mass of 235 units, as compared with 238 for the common variety.

It was discovered that if an atom of U^{235} absorbs a neutron of low energy, an unstable system is created which very soon breaks up, giving off several fragments which carry away an enormous quantity of energy in a form which is readily convertible into heat. At the same time more neutrons are emitted.

If, now, these neutrons can be slowed down while still in the vicinity of other atoms of the same element, that is if the process can take place in the presence of a sufficiently large mass of the substance the slow neutrons so formed can be absorbed by more atoms, leading to the emission of still more energy, and also of still more neutrons which in their turn can bring about the fission of more atoms and so on. In this way it is believed that a chain-process may be set up under suitable conditions whereby atomic energy may be liberated at an enormous rate. One estimate, for example, suggests that one cubic metre of uranium can develop one million million kilowatt-hours in one hundredth of a second.

Any reaction of this order of violence would be entirely new in human experience. A more controlled reaction in which, at a rough estimate, a million kilowatt-hours of energy could be released in a hundred seconds would be sufficiently violent for our purpose. When the fission process is thoroughly understood and the precise nature of the process of controlling the emission has

been worked out we will have at our disposal a source of energy of a very much higher order of magnitude than any produced by chemical means. Such a discovery would remove the major obstacle at present in the way of our visiting the planets.

Since the outbreak of the war a great deal of work has undoubtedly been proceeding in this connection, but on account of the obvious military potentialities of the process no results have been made public. It is not impossible that the investigations now proceeding may in our time yield the secret of atomic power with all that such a discovery will mean.

7. There remains one further question that I would like to discuss very briefly. Suppose that in course of time it becomes possible to visit the planets. What will those early space-travellers find? Are the planets inhabitable? Are they inhabited?

Unfortunately, at the present stage of development of astronomical science it is not possible to offer a definite answer to those questions in the majority of cases. We know that the Moon is an airless, waterless, dead world. So, it would appear, is Mercury. But the other planets have atmospheres. Venus seems to have a very dense atmosphere, almost entirely cloud-covered. Unfortunately, recent researches seem to indicate that the clouds are not due to the condensation of water-vapour and further that oxygen is lacking in the atmosphere of this planet.

Mars presents the most interesting case. It seems that Mars possesses life, at least in the form of vegetation covering large stretches of its surface. But water is exceedingly scarce and the atmosphere appears to contain very little oxygen or water-vapour. However, the observations are exceedingly difficult and no great accuracy can be claimed, so that the possibility exists that Mars is both habitable and inhabited.

Of the remaining planets we can say very little. They possess extensive atmospheres in which occur dense cloud-layers over the entire surface. Unfortunately for our space-travellers here, too, conditions would prove very difficult, since it is believed that the temperatures of these planets are very low and the clouds are due to the condensation of substances with low boiling points such as methane and ammonia.

It is, therefore, doubtful whether the visitor to the planets will find conditions suitable for human life. All that we can hope for at present is to be able to get to the planets—not to be able to stay there.

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SYMPOSIUM

ON

A SCIENTIFIC APPROACH TO THE PROBLEMS OF POST-WAR EMPLOYMENT

WEDNESDAY, 5TH JULY, 1944, IN PLENARY SESSION.

Chairman: (Morning Session) The Hon J. G N. Strauss, Minister for Agriculture and Forestry; (Afternoon Session), Mr. F. A. W. Lucas, K.C.

Conveners: Professor John Phillips, Mr. Jas. Gray, M.P.C.; Dr. J. B. Robertson.

CONTENTS.

(1) INTRODUCTORY REMARKS

BY

THE HON. J. G. N. STRAUSS.

The reason why I have been asked to preside at this Symposium is probably that as no Department of the State has made such extensive use of scientific research as my department, it has been desired to assist me in finding solutions for the problems by which I am confronted. In all the years that the Agricultural Department has been assisting the farmer to surmount his difficulties, it has relied upon scientific research as the foremost method of attack. Although I cannot give you the figures for the sum spent annually on agricultural research, a glance at the annual estimates will show that a very large part of the funds entrusted to the Department of Agriculture was spent directly or indirectly on research.

The painstaking and patient perseverance of the research workers led to throwing open certain areas previously unsuitable for farming. The progress of agriculture in the last 25 years and the more modern methods of production employed by many farmers to-day could be traced to the results of research.

The department employs 400 research workers. In addition to the institutions and laboratories in Pretoria, there are five colleges of agriculture where research is conducted and about 40 research stations throughout the country. There are also two university faculties of agriculture where the research work has been taken over by the department. This has been done with regard to pasture research and also at the Rhodes University College with respect to Leather research. There is a great need for more co-operation of this kind, and I would sincerely welcome efforts in this direction. I must emphasise that the agricultural research facilities at present available in this country are not nearly sufficient for our requirements.

The time must come when we shall have to expand considerably, there is a need for more technical staff, more experimental stations and better co-ordination of agricultural research, more particularly with a view to making the fullest use of the facilities available at the universities and fitting this research into their general programmes.

One of the problems and difficulties I have found since taking over my portfolio is that scientific workers in the department consider their emoluments quite inadequate. We attract some of these men from the universities, keep them for a time and when they become really useful they get more attractive posts elsewhere. The State then loses their services.

This is a matter that will have to be carefully considered and rectified; for I feel that the State is in very great need of the services of these scientific and technical workers.

This symposium is devoted to the study of post-war employment, a question which is becoming one of the biggest issues in all free countries and not least in South Africa. Here we have fortunately learnt from the experience of the last war that it is necessary to prepare ahead to meet post-war problems The ideals for which we are fighting—the freedom and happiness of mankind—can only be maintained if each and every individual is granted the opportunity of earning sufficient to support himself and his family at the accepted standards of living of different elements of the population. That is the task of our Country. Our tens of thousands of soldiers have to re-enter civilian pursuits, our thousands of war-time factories have to be reshaped and remoulded to produce goods for peace-time consumption, and our natural productive resources have to be developed.

The Government is fully alive to the problem of employment after the war and has already set up bodies to study its different aspects, but it welcomes the contribution to be made by this Association, many of the members of which are already serving the Government in various capacities.

We have come to appreciate the value of the pure scientific analysis of a problem, but Ministers who have to guide the destinies of a country sometimes do not find it possible to give practical application to all the logical conclusions of the scientist.

At times the scientist may become impatient with the statesman, but though scientific facts might be indisputable and might point out a definite direction, practical policy might dictate other roads than the direct one to the same goal.

Much has been written about the inefficiency of South Africa's agriculture, which has, however, provided the country with food during the war years and would also be willing to contribute its fair share to the post-war structure. I and my department are fully conscious that our agriculture needs readjustment in conformity with the natural controls, and I want to give you the assurance that I will do my best to bring about balanced farming systems in the various areas of the country.

The urban population is beginning to appreciate the difficulties of the farming community and is becoming "soil conscious." The city dweller is gradually realising that the farmer, equally with the wage-earner, is entitled to social security and to remunerative return for his labour.

Owing to agriculture's extremely low contribution to the national income relatively to the population engaged in farming, agriculture on the existing level will not be able to absorb a

very large number of new entrants. The main agricultural problem for the future is to raise the productive efficiency of those who are already on the land.

While, to my mind, agriculture's main contribution to the employment problem will be to maintain and better the lot of those already there. there will be scope for the right type of newcomer, one who loves the land, who is armed with the knowledge science can give, and will look on farming not only as a means of livelihood, but as a mode of living—one who, above all, is endowed with the spirit of perseverance.

Employment cannot be created by Act of Parliament or by Government action alone. The most Government policy can do is aim at bringing about conditions favourable to the maintenance of a high level of employment. The success of such a policy will depend ultimately on the understanding and support of the community as a whole—especially on the efforts of employers and workers in industry.

Without a rising standard of efficiency in industry, in its broadest sense, we cannot achieve a high level of employment combined with a rising standard of living.

It is the Government's aim that the whole production power of the country should be employed efficiently, but the great need, in order to have any measure of social security, is to increase vastly the national income. The Government is committed to that policy. Our aim is to achieve work for all and a progressive increase in the economic efficiency of the nation as a whole, as joint elements in a growing national power to produce, to earn and enjoy the fruits of increased well-being.

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(2) SCIENTIFIC APPROACH TO POST-WAR EMPLOYMENT: AGRICULTURAL ASPECTS

BY

DR. THOS. D. HALL.

" 'n Plan is 'n Boerdery," is generally accepted as sound, but when one individual presumes to suggest plans of employment for agriculture as a whole, he attempts a task of considerable difficulty. It is thus with true humility that I venture to voice a few ideas on a subject so intricate.

For many, post-war planning has become almost a popular pastime, for others, it is a form of escapism from the unpleasant realities of to-day. I recall a humorous drawing in which the artist depicts a large dinner party of prosperous people and the caption reads: "Archibald—I'm ashamed of you, the only husband here without a post-war plan."

The Pattern of the Future. To my mind, it is of little use formulating plans for settlement or production in agriculture unless we have some idea of what is the pattern of the future into which we have to weave them. A design of living at once so vast, so intricate and so dynamic cannot have the simple static plan of a Persian rug. We must have some idea of the extent to which we are to be internationally interdependent, or nationally and economically exclusive, if any worthwhile plans are to be formulated.

International Relations. The Moscow Conference agreed that some form of international organisation was essential for world stability, and the form suggested seemed very much like a revived and improved League of Nations, with the sovereign independent state as the unit of association. The need of armed force to maintain law and order was agreed on, and to the big four of the United Nations it was decided should be given the task of seeing that the smaller nations are allowed to govern themselves as they wish. For this purpose the big four are to be allowed to keep their armaments. Recent utterances by Mr. Churchill and General Smuts, make it look as if this is the plan which still finds most favour among the United Nations.

If there is one thing most economists seem agreed on, it is that it was the national sovereign state with its attempt at economic independence which landed us all in the international chaos which ended in the present world conflict and misery. Professor Leppan, in handling this theme two years ago, made this point in some considerable detail, and also said that the future lot of farming depended largely on the extent to which intentions underlying the Atlantic Charter were put into effect.

Internationally, there has been considerable activity since then and much excellent co-operation on a regional and functional basis, but the ordinary man is not yet satisfied as to the manner in which the Atlantic Charter is to be interpreted. The Combined Raw Materials Board and the Combined Shipping Adjustment Board have contributed substantially to the success of the United Nations. There has been a pooling of shipping, joint economic boards and many conferences and consultations. A combined Food Board was also set up in 1942, by Mr. Churchill and Mr. Roosevelt, and also a London Food Committee, and then came, in my opinion the most important of all the Conferences with regard to the future.

THE UNITED NATIONS CONFERENCE ON FOOD AND AGRICULTURE.

This is one of the most important conferences ever held in the history of mankind, and one to which not enough publicity has been given In this conference, held at Hot Springs, Virginia, just over a year ago, 44 nations took part, and a most hopeful spirit of co-operation prevailed throughout the proceedings. The findings of this United Nations Conference on Food

and Agriculture, which I shall call UNCFA for short, to contrast it with the better known UNRRA, are fundamental, and we must spend a little time on some of them. More than two thirds of the human race is occupied in producing food (most of them inefficiently). The fundamental interdependence of consumer and producer was stressed, and the necessity for nations to consider their food policy and their agricultural policy together and also that better nutrition means better farming. The conference, after considering the world problems in food and agriculture, declared its belief that " the goal of freedom from want of food, suitable and adequate for the health and strength of all peoples can be achieved." " There never has been enough food for the health of all people. This is justified neither by ignorance nor by the harshness of nature. Production of food must be greatly expanded, we now have the knowledge of the means by which this can be done. It requires imagination and firm will on the part of each government and people to make use of that knowledge. . . . ."

" The first cause of hunger and malnutrition is poverty. It is useless to produce more food unless men and nations provide the markets to absorb it. There must be an expansion of the whole world economy to provide the purchasing power sufficient to maintain an adequate diet for all. This is done to a large extent in war—why not in peace?"

It was realised of course that this was a long term policy, and that in the meantime it was a question of preventing hunger and starvation in certain countries rather than providing adequate diets, and so the United Nations Relief and Rehabilitation Administration came into being last November and is now functioning. We are contributing to UNRRA at least £500,000 in cash and kind. All available surpluses of food are for the present earmarked—but what of the future? UNCFA provided for an Interim Commission to be installed in Washington—on this each country could have one delegate. The commission was given the power to formulate a plan for a permanent organisation in the field of food and agriculture and to go into many matters and details which will be required by the nations to make the plan work. Has our Government accepted the resolutions of this conference, even in principle? Has South Africa a representative on this Interim Commission and if so, who is he? Perhaps the Minister of Agriculture—present here to-day—can enlighten us. One thing is sure—we are much better prepared for peace than we were in 1918, but peace is no panacea. People must be made to realise that the problems of peace will be, if anything, greater than the problems of war.

The Position of Our Country. To refer to South Africa for a minute, that most excellent report of the Department of Agriculture, " The Reconstruction of Agriculture " considered what South Africa could do with regard to UNCFA. and concluded that, with better methods and sounder conservation, our

farmers could rise to the occasion, provided there was the opportunity of selling their products at a profit. It was thought that improved methods could bring down the costs of most products.

In some respects, our country has already met a few requirements of the recommendations of UNCFA in "The Reconstruction of Agriculture" report, the report of the Social and Economic Planning Council, and in the "First Report on the Activities of the National Nutrition Council" which show how great is the necessity for those products which require intensive agriculture for their production if the nations' health is not to be more seriously impaired than it is now. Both Councils think that the control system should be based on proper national nutrition and the conservation of farming resources. The Ministry of Welfare and Demobilisation, in co-operating with other State Departments is also approaching its problems realistically. At the present time the farmer can sell all he produces at a profit, only because there is full employment under war-time pressure. Can man plan his world of the future on the basis of an economy of abundance? Will there be proper international co-operation in production and distribution? If so, agriculture will flourish and post-war employment will be no problem. If we try to go back to economic independence and subsidised exports, we shall probably have more unemployment and misery than ever we had in the past. There seems to be ample evidence that we are trying to improve our social and economic conditions on a sound evolutionary basis, and that we are well aware of our past imperfections. This is encouraging for the future.

Agricultural Settlements for Post-War Employment. To leave the broader aspects for a while, what are the prospects of settling returned soldiers on the land? Not many were settled after the last war and the percentage of failures was high. To-day, we know some of the causes of these failures, so we ought to do better. Let us glance back to a few facts with regard to settlement after the last Great War. I am indebted for these to a memorandum by Professor J. Orr, the Director of the Witwatersrand Technical College on "The Rehabilitation and Training of Ex-Service Men" dated November, 1941. This deals largely with the experience gained under the administration of the Governor General's Fund. Although £3,033,218 was spent on general relief and assistance to ex-soldiers and their families, only £33,348 was spent on the settlement of ex-soldiers on the land. Regarding this the report states "It will I think be admitted by all connected with the fund, that the efforts in this direction had most disappointing results. Assistance was given in the form of capital grants and loans, one-fifth of the purchase price of the land being commonly provided. Successes were very few, and the great majority of the loans were written off years ago.

In addition to capital assistance, a large number of ex-soldiers received training on farms and at agricultural colleges with a view to their being in a position at a later date to benefit from the facilities offered by the Land Settlement Department. At the middle of 1920, the following were receiving such training:—138 admitted to Government training farms, 370 admitted to private farms and 391 admitted to agricultural colleges.

The fund has only given capital assistance in cases of disabled soldiers, and exceptionally, to non-disabled soldiers in special cases of long service and special sacrifices to go on service."

In this connection, the post-war expenditure incurred by the Union Government was £149,799 for giving returned soldiers training in agriculture, while forestry scholarships and employment of ex-soldiers at Government Plantations amounted to another £15,370. The Department of Lands probably incurred very much more expenditure in actually settling service men on the land, and the Land Bank also played a big part in this work.

The Position To-day. Much experience has been gained since the last war. All proposed irrigation settlements are investigated very thoroughly by the Division of Chemistry and a most detailed soil survey is done, on which the suitability of the soil and the types are judged, and areas classified for various crops. Much has been learnt in the past twenty-five years, and the recent irrigation settlements of the Lands Department have achieved considerable success. This department is determined not to repeat the mistakes made after the last war when, to quote "The Farmer's Weekly" of 15th December, 1943, "It attempted to settle inexperienced men without training or supervision." "Now," this paper states "gratifying emphasis is throughout placed upon advance preparation of all land held and acquired by the department for occupation by returned soldiers." To-day we are told, the Lands Department is preparing settlements for about 3,500 returned soldiers. About 2,000 of these will be settled on irrigation projects like the Vaal-Hartz, Riet River and Loskop, and the rest on larger dry farms, chiefly for cattle breeding and sheep farming. The land will be prepared and ready to be taken over and there will also be a house. The cost of improvements like boreholes and dipping tanks is, however, to be added to the purchase price. It is made clear that the plots and farms will be allotted only at the end of the war, when all the men are back, and then only to fit men. When all the applications are in, then the most suitable settlers will be chosen by a selection committee on which the ex-soldiers will be represented. Then follows a five year probationary period, but men who are good and prove themselves thoroughly competent and reliable can become lessees of the Crown land on which they have been settled in just over a year. A period

of 63 years is allowed in which to liquidate their indebtedness to the State. Canada allows only 25 years. For the first few months they get £5 a month in cash and are helped with fertilisers and general guidance. In the experience of the Lands Department, if they can get suitable men with an agricultural background, they believe they can teach them the best way to handle the crops for a payable rotation in their area, say lucerne, potatoes and wheat, without sending them to a special training centre. On the irrigation settlements in many cases, mowers and other implements have to be shared and the farmers are charged for the service they perform. When we read that the Lands Department has settled only 9.133 men in all under Section 16 of the Land Settlement Act, in the period 1910-1940, then we must realise that a special effort is being made to prepare for 3,500 returned volunteers. It is of more than passing interest perhaps to recall that the small and thickly populated country, Greece, after her last war with Turkey, had to accept and settle 551,468 Greek refugees and apparently did it with some success on 839,044 hectare.

Although no soldiers will be settled permanently on these prepared holdings, until after the war, soldiers and civilians alike can select and obtain land under Section XI of the Land Settlement Act and also from the Land Bank. In the thirty years previously referred to, 6,463 were settled under this section of the Act.

With regard to less fit and semi-fit men, we are told the Department of Welfare and Demobilisation, State Advances, the Land Bank, and the Department of Agriculture, are taking a hand. The Directorate of Demobilisation has a Special Land Settlement Co-Operation Committee, on which representatives of Agriculture and Lands are serving, four M.P.'s, a soldier representative and the president of the South African Agricultural Union. The co-ordination work of this committee is badly needed, and its report will be awaited with great interest and will probably result in beneficial co-operation among the departments most concerned.

Volunteers Already Discharged.—What of the men already out of the army who want to farm? They can be catered for under the arrangements already mentioned or else they can undergo some training while waiting to take up land. The training would have to be on a private farm, as so far the Department of Agriculture has done nothing about training men to go on the land, although courses may be started at the Agricultural Colleges shortly. Men are already taking up land under Section XI, many ill prepared and on units too small and too expensive for any hope of success. Should not all applicants for land be made to take at least a six months practical course, so that it may be ascertained if they are really experienced enough to take up a holding? Should not these holdings be

properly developed, not only as regards fences, boreholes, dipping tanks, but also in the layout of lands and camps in such a way as to ensure that soil and veld conservation practices are carried out? This is where there could be more co-operation between the Departments of Agriculture and Lands. It is worth considering for the sake of proper soil conservation methods, whether all state land should not be issued under perpetual lease (erf pag) rather than sold. The tenant has the right to bequeath the leasehold and has all the advantages of ownership. The State, however, would be in a position to insist on proper conservation methods in the terms of the contract. This proposal is made in the Reconstruction of Agriculture report and seems to be eminently sound and practical. It would also enable the average man to spend more money in developing his plot properly.

The Industrial and Agricultural Requirements Commission is of the opinion that there are already too many on the land and that industries should be planned to absorb the surpluses and get a better balance. This is no doubt a realistic approach for things as they are to-day, but if the future is better planned than the past, it may be otherwise.

Rehabilitation Settlements.—A good many influential and responsible organisations have put up suggestions that settlements of the nature of those in Palestine should be tried out here. The Minister of Lands dismissed the suggestions on the grounds that the schemes are un-South-African and not suited to our farmers, who are strong individualists. It was not suggested that they should be applied to South African farmers, but to returned soldiers, many thousands of whom have visited the communal, collective and co-operative settlements in Palestine and the Italian demo-graphic settlements in Tripoli and Cyrenaica and have been much impressed with these well-planned settlements. Let us approach the problem from another angle. Thousands of men have been nearer the land than ever before and have learned to love it and dread going back to an office life. Others have acquired disabilities which make indoor work undesirable, and many others just want to farm, but may be quite unsuitable for it and tire of it quickly. Then again, these plans would have some worthwhile value as socio-agricultural experiments. Too many men after the last war received only short courses at Agricultural Colleges. I think they should have those courses only after they have made good for at least six months by hard work on a settlement. These settlements could be considered, not as permanent settlements, but as a means to an end, e.g. for:

1. *Selection:* i.e. to show up the man quite unsuited for the land and also his wife, because if she does not like the type of life, he is not likely to be a success.

2. *Training bases in Agriculture*. To enable the trainees, by doing the work themselves to be able to direct others in due course.
3. They would have psychiatric value in allowing the shocked and ill adjusted man to find himself. Many will be abnormal, depressed and nervous and this will give them a chance to re-orient themselves. This has been done with success on the Sidi Mesri Agricultural Experimental Station in Tripoli.
4. These types of settlement are the cheapest way of giving the men the agricultural experience they want. For those who like either the individual-collective or co-operative life, it will be the cheapest way for them to practise farming and will give them a sense of security—which they will not have as an individual farmer. The individual-collective type of settlement was the type favoured by Captain H. Cornell in his excellent report on his visits to the Palestine Settlements. Major R. L. Robb, now Director of Agriculture in Tripolitania, also visited the Palestine Settlements and has had considerable experience with the Italian demo-graphic settlements. In his recent report "Organised Land Settlement in the Post War World," he also strongly favours the individual-collective type of settlement The settlements of the Nederlandse Heidemaatskappy which I visited, although having individual holdings, centralised the dwellings into an attractive village and the director stated that, unless there is a church, a village hall, a school and buildings for shops, the farmers will not buy the land. Furthermore, the land was thoroughly prepared and had almost mature crops growing on it when the settler arrived.

Various Types of Settlement.

1. *The Communal Farm.*— This type is not likely to find much favour in South Africa, although even here some groups could no doubt be found who would like to try it, and should be allowed to do so. I consider the communal type of farm merely as a cheap and efficient way of getting in some practical training and as a means of sorting out the misfits and making some adjustments. It would play an important part in showing up the wives of ex-service men who are unsuited to farm-life. I make the suggestion, that one of the Agricultural Colleges could be tried on a modified communal basis. This is a suggestion not likely to find favour when first heard, but I speak with some experience of such training, having taken part in it during 1919-22.

One of the difficulties about the agricultural colleges is, that apart from a short training, which provides little practice and responsibility, men could not have their wives and children with

them. This makes many restless and dissatisfied. Many of those returning will hardly know their wives and may have children they have never seen. These schemes would also give the wives an idea of how they liked farm life and only couples should be taken on where the wives were prepared to work. Accommodation will also have to be made for children. Major Robb, reporting on the Palestine Schemes recently says, he has never seen healthier children than on these communal settlements. The communal farm would be the cheapest way and handle more units to start with—but a big wastage could be expected here, perhaps 50 to 60 per cent. My idea is that at one Agricultural College at least, couples with and without children should be taken on. The married couples are each assigned a room, but if not enough come forward, the rest of the rooms can be filled with unmarried candidates. The children must be housed separately in hutments specially provided for them and be divided into three age groups, say one-three, four-seven and seven-sixteen. The older children could go to the nearest Government school and a nursery school could be organised for the younger group. They would be in charge of a properly trained nurse and a matron who would be assisted by the mothers according to a regular schedule. In other words, in this socio-agricultural experiment, the women should be given practical work in mothercraft as well as household science and practice in poultry keeping, dairying, beekeeping and horticulture. They would be busy as well as their husbands, and yet for a few hours a day they would be able to enjoy their children. As much work as possible not only on the farm, but in the hostels, the creche and nursery school should be done by the trainees. After dinner, groups could meet to discuss the practical work of the day and also explanatory lectures should be given.

Difficulties regarding the administrative, extension and research work of the college will be real, and the ideal training centre for such a plan would have to be started *de novo*. Time is, however, short and as most of the accommodation and equipment is already at the colleges, I think a practical training course of this nature should be tried. Those who pass through this test of practical and communal work and still want to farm, could then go to the second type of settlement.

2. *The Individual-Collective Settlement.*—This type, with its individual houses, and small plots would cost more, but would appeal to most people far more than the communal type.

One of the causes of failure in the settlers after the last war, was the loneliness of the women—the lack of social contacts. It was often in seeking these amenities that more money was spent than could be afforded and the farm suffered. In an individual-collective or co-operative settlement, there would be no question of keeping up with the "Joneses," they would all be "Smiths" together, and they would be within easy

visiting distance. Many wish to try farming and would like the life, but they feel that it is too uncertain and they cannot face the responsibility, whereas, with collective or co-operative responsibility having a sense of security, they would be quite happy. To many, the human contacts and sense of security would have a greater appeal than an individual farm. Many enjoy this type of life quite apart from its freedom from want or fear. If they have only a small gratuity or limited capital to invest, they could do it more safely here than as individuals. The cost per individual will be from £750 to £1,200, depending on the area chosen, this is judging by Palestine experience. There should, however, be a community hall, an office, a school and a co-operative store, a dairy and some workshops and a central machinery depot. To make this type of settlement more independent and self-supporting, rural industries should be encouraged and particularly the preserving and drying of foodstuffs for the non-growing periods. With most of the land collectively worked, there would be a big saving in machinery costs.

From the individual-collective type, there could be a transfer to the co-operative type.

3. *The Co-operative Settlements.* — With each plot run individually, will appeal to many—these settlements could be modelled on those of the Lands Department. I think they could be improved, however, by providing a community centre as detailed under 2; and by embodying some of the ideas of the Italian demographic settlements.

4. *The Individual Type*.—At the end of four or five years, those who still wanted to farm and had proved themselves, could go completely individualistic if they wished and take up a larger farm on their own. They would then be fully prepared and confident of their ability to carry out farming operations. In all, I think there will be required for training at least two of the communal types for preliminary training and two each of the collective-individual and co-operative type. One of each could be on irrigated land and one of each on dry land in a good rainfall area like Natal or the Eastern Transvaal. The two latter types could be made permanent settlements when the training period was over.

The Italian Demographic Settlement.—A word should be said about this type of settlement, which resembles our Lands Department irrigation settlements in some respects. Emphasis is laid on the family however, and not the individual. The minimum family unit accepted was eight. The outstanding features of the Italian Demographic Settlement schemes says Major Robb are the conception, organisation and pre-settlement planning, with the provision of services to meet spiritual, social, cultural and other needs of the settlers after occupation. Not only was prepared land provided, water, livestock, implements and a house, but also furniture, and foodstuffs for a week. For

the first year or two, the settler receives a monthly salary of £6 10s., but all his produce is taken. His farm and domestic requirements are, however, financed. Later, only half his produce is taken. When the settler can carry on himself he becomes the owner, and liquidates any outstanding debt. Although the planning of these settlements was excellent, their cropping schemes were not worked out in accordance with climatic limitations, but with the food requirements of Rome. This did not give the settlers a fair chance. There was too much political pressure to make these settlements a success, and many were occupied only just before the present war and before they were ready to receive the settlers who, in some cases were inexperienced and quite unsuited for the land. The most successful were those where the land had been properly prepared and the people of farming and peasant stock.

We have much to learn from these various types of settlement and I can see only advatnages in trying out a few of these schemes, if only as a means of adjustment and rehabilitation and of training farmers and sorting out the misfits with a minimum of expense.

Bantu Settlements.—I see no reason why some of these schemes should not be tried in the Bantu Territories, as they would be under good control which would insure proper soil conservation. They might be even more of success there, as the Bantu have a lower standard of living. We seem slow to realise the economic value of the Bantu population. Only if their buying power is increased will agriculture and industry flourish. Whereas the mines appreciate the increased value of labour properly fed and housed—it does not appear to be the case in agricultural areas. Poorly fed, clothed and housed, agricultural labour is inefficient and expensive in the end, and there is no doubt that the farm labourer of the future must get better treatment and he will respond with better service. Why is it we cannot compete with the more expensive farm labourer of Canada and Australia? One reason is that our cheap labour is not efficient and is in the end often more expensive. One of the first men I ever heard express the idea that South Africa would never flourish industrially until its Bantu population had more buying power was Andries van der Post in 1915. He is now our Trades Commissioner in London and one of the signatories of UNCFA. He was also vice-chairman of the committee which dealt with special measures for wider food distribution including: (1) Improvement of consumption of low-income groups. (2) International disposition of commodities in over-supply.

Employment Under Land Reclamation and Conservation Works.—The achievements of the United States Civilian Conservation Corps have been adequately advertised, and well they deserve to be. Up to 1940, two million men had passed through the camps of the C.C.C. and returned to private life as respon-

sible and self reliant citizens. At one time there were 1,500 camps averaging 200 men each on Soil Reclamation and Forestry projects. In America the C C.C. has proved indispensable and has come to stay. The German Labour Corps, which required each fit young man of whatever origin to serve his country for a year in State development or reclamation work, had a sound idea. We should do something similar, but train our youth for constructive but not destructive work. Our experience with our own S.S.B. was most satisfactory and education, discipline and diet worked wonders. There is so much work to be done with regard to Land Reclamation and Rehabilitation that we should endeavour to establish something similar to the American C.C.C. There would be numerous jobs for returned ex-service men and also non-European returned soldiers. The work is there if the State can find the money. Returned men who have no other employment should be given a chance to enrol, but there will also be jobs for semi-skilled and skilled men, such as drivers for lorries, graders, ditchers, scrapers, bulldosers and for mechanics of all kinds to service these machines. Men could also be trained to lay out contours on veld and cultivated land and design the storm water control on farms. Their services would be in great demand when they had finished their training. Many of the men who enrolled in the American C.C.C. returned to rural communities and farm homes where their training and experience aided them in finding employment, and they were a means of spreading soil conservation principles and practices.

There will surely be much material available from the U.D.F. after the war in the nature of spades, barrows, concrete mixers, stone breaking machinery, bulldosers and all sorts of graders and ditchers. Mobile mechanised units of the C.C.C. or National Service Corps, which I prefer, who could tackle and finish a job quickly under the direction of officers of the Division of Soil and Veld Conservation, would be a boon and a blessing to farmers, many of whom would be quite willing to pay for their services. There are many farmers who wish to tackle their soil erosion problems, but have not the experience or the labour to do so There is no doubt that these Mobile Mechanical Units would do the job more cheaply and efficiently than individuals.

The question of policy is important. These mobile units should not run around tackling isolated farms but say—a valley watershed as a whole. Efforts must be made to get a group of farmers in an area to combine and agree to co-operate so that the conservation can be planned irrespective of boundary fences. It is no use one farmer doing even a perfect job of erosion control or soil conservation if his neighbours above him are indifferent, as they will cause all his pastures and dams to be silted up and even to wash away. A valley at least must be tackled as one unit. Then it is not only among farmers that

co-operation is required but among State Departments. Farms belonging to the Lands Department, the Department of Agriculture and the Department of Native Affairs may adjoin each other in one watershed. Proper erosion control can be done only if the whole area is treated as one unit. If each department tries to carry out its own work, chaos is likely to result, or at least heavier expenditure. It is a realistic situation that must be faced.. I hear rumours that something of the kind has already arisen.

Perhaps the easiest way to get the C.C.C. scheme going would be with the help of the Department of Defence. Its camps could be used to house the men enrolled to start with and they could remain under military discipline, in fact the whole camp organisation should be under Defence. The selection of areas to be worked on the actual planning and assignment of the work should be the duty of the Division of Soil and Veld Conservation. Camps should be mobile, with hutments which could be easily taken down and reassembled. Not more than 200 men should be in camp. Some of the camps would be assigned to Forestry Officers. The C.C.C. or N.S.C. should be a permanent organisation for employing and training youths even after all the discharged men have been dealt with. Some areas badly eroded might be proclaimed Conservation areas and dealt with and the most promising men afterwards settled there, after reclamation, on condition they maintain the improvement.

The reclamation of nearly one million morgen of land from prickly pear and jointed cactus and some 36,000 square miles from thornbush encroachment to recover the pasture, would also be worthwhile and productive work. There is, however, real danger that lack of trained technical staff in the Division of Soil and Veld Conservation would not allow these proposals to be put into effect. This is a serious situation and salaries should be paid such as can attract able young men to this work of real national importance. The need is great and the training of men to train others really urgent. This generation and those that follow must be taught that they are the custodians of the land and that it must be used and passed on as good, or even better than they found it. The means of doing this must be amply illustrated by the conservation units, officers of the Department of Agriculture and good farmers. The C.C.C. or N.S.C. Units could be used to put proposed settlements in order and at times even in production in the ploughing up and preparation of land, and in harvesting crops. We have seen how valuable has been the work of the U.D.F. Units in assisting with the transportation of maize, wheat and kraal manure. If there is proper co-operation between the Departments of Agriculture and Defence, I think a scheme of real value and at minimum cost to the State can be initiated. This scheme should be able to give employment to some thousands of ex-service men.

The Minister for Native Affairs is already planning to use the returned Bantu Volunteers in his policy of land rehabilitation

and agricultural uplift. Thousands of these are trained lorry drivers and have worked with our engineering corps and are eminently suited for the work.

We have discussed some aspects of employment in agriculture. To what extent they can be implemented depends ultimately on the decisions of the United Nations as regards the Hotsprings Conference on Food and Agriculture and the consequential structure of world economics. If we try to put into effect internationally and nationally the resolutions of UNCFA, it means a great expansion in intensive agriculture in the production of dairy products, eggs, fruit and vegetables, to get the diets balanced for health. It means much more employment in agriculture and a chance to increase the population in the higher rainfall areas considerably.

One of the world's greatest authorities on nutrition and also an experienced soldier, Sir John Boyd Orr, M.C., D.S.O., F.R.S., wrote these words long before the Hot Springs Conference: "Now we are in the middle of a world-wide war for the complete freedom of the common man. This war is not merely a defensive war to bring about economic freedom to all men of all lands, to the vanquished as well as the victors. The fight for economic freedom will not necessarily be won when the Nazis and the Japs are defeated. It will not be won until all mankind have sufficient of the necessities of life to enable them to attain their full manhood. Only then will man be completely free. Only then will his hold on political freedom be secure." I think Sir John Orr's book "Fighting for What?" should be given to everyone to read. To me it is so sane and sound that I make no apologies for quoting it. He says what I'd like to say, but says it more strikingly and effectively.

He says in his foreword that so many politicians have been so occupied with war measures that they do not realise the extent to which the burning desire for a better post-war world has grown and spread among all classes of our people. "We shall not go back to the pre-war world with its slums, unemployment and poverty. The main function of Governments will be the promotion of the welfare of the people governed, and the food policy will be one based not on trade interests, but on the nutritional needs of the people"

The way our Minister for Agriculture has stood up against all opposition for his meat scheme, which is designed for the good of the greatest number, augurs well for the future, and makes me believe he will initiate other bold and necessary measures when once he gets into his stride. It is of more than passing interest to note here that Dr. van Eck, when addressing the symposium in this hall two years ago was quite prophetic when he said, "One visualises the sale of carcases at standard prices based on careful grading." He said a lot more, but perhaps the rest will come about too. There are always grumbles and critics of every ministry, but has any government initiated

as much social and economic reform in the whole history of South Africa as the present one?

To return to Sir John Orr for a minute, the main thesis of his remarkable book is that " If we are planning for human welfare, we must put first things first and concentrate on food, houses, and a job. Whatever obstacles prevent us from providing these necessities must be ruthlessly removed. Everything else in the social and economic structure should be left standing in the meantime."

In conclusion I would like to say that whether or not there will be plentiful employment in agriculture, depends largely on what is the attitude of our Government and the other United Nations to the resolutions of UNCFA, which I consider of fundamental importance. Do we believe that the whole is more important than the part and are we prepared to surrender some national sovereignty to an International Central Authority for the sake of world stability, peace, and a better lot for the common man? Can we believe that " this policy of directing economics to social ends is good, not only for the people, but also for business?"

Something positive, which will be of benefit to all, will do much to cement the nations together.

If the United Nations proclaimed to the world that their post-war food policy was to be based on human needs, it would put new resolution into all soldiers and workers to strive harder for a victory which would initiate a new international era, and also encourage the peoples of the occupied countries. Very idealistic and Utopian I can hear some of you saying, but so impractical. Well, if your idea of practical politics is the confusion and chaos in the 21 years of the pause between wars, let us try something new. To plan now, with faith in the future may possibly be not Utopian, but the most practical action we can take. Remember that Lord Keynes, now leading the British Economic Mission to the United States on monetary matters, was considered by the great statesmen of Versailles to be an impractical dreamer. Mr. Keynes' book " The Economic Consequences of the Peace " proved itself to be more practical than the decisions of the Peace Conference. Washington, when speaking at the Convention which initiated the Federal Government of the United States, spoke against compromise and urged the convention to have some faith in the future. His words " Let us raise a standard to which the wise and honest can repair. The event is in the hand of God." Measures were taken, not to please, but to save the country. His council prevailed and a great experiment worked.

Let us drop all thought of *status quo* and endeavour to build better for the future, a real structure of international co-operation which will reduce economic wrangles to a minimum and give the world some social security and peace. Then employment in agriculture will be no problem.

(3) EMPLOYMENT IN THE POST-WAR WORLD

BY

J. CALDER,

Secretary, Electrical Workers Association of South Africa.

I speak as one primarily interested in the engineering industry, but a no less interested citizen of South Africa, and I hope that my small effort here this morning will give you an idea of the magnitude of the task facing Southern Africa in the post-war world.

Apart from the actual war itself, the subject which is uppermost in the thoughts of thinking men and women today is: What kind of world is it to be after the war? and a conclusion cannot be reached until machinery is created to provide universal employment, to abolish our slums, to ensure medical attention for all, to give opportunities to all sections of the community, to better their conditions, and, in short, to achieve a considerable measure of social security. As a first essential to the accomplishment of these things, and to provide a better standard of living, it is of paramount importance that all workers should be given security of employment and the right to share in the wealth their labour produces.

The economic history of South Africa is largely the history of the gold mines, and our industries have largely centred around the activities of the mines; consequently, our engineering industry is mainly one for manufacturing and repairing equipment for the mines and for other industries, such as railways and power installations, which are closely associated with the mining industry. In consequence, the workers in the engineering industry are predominantly journeymen and/or apprentices, with a sprinkling of operators, and our cost and wage structure has been determined by other than manufacturing factors.

The advance of science and invention and their influence on modern industry has tended to bring the use of machines more and more into the orbit of the semi-skilled person, and at first glance this might suggest a limitation of employment for the skilled man; but, on the contrary, the more semi-skilled persons are employed in operating machines in various industries, the more scope will be created for employing skilled men in the manufacture, maintenance and repair of machines, which in our time tend to become more intricate. It follows that trade unions must move away from the secular and "preserved trade" ideas of the past, and adopt a wide and more fluid approach to matters of wages and conditions. It may be truth-

fully said that the employment of operatives, subject to proper regulation, is a guarantee of employment to the skilled man. While a great deal can be done, and must be done, to develop agriculture in order that we can feed the people in the country, it can, I think, be safely said that our industrial possibilities offer a greater scope for employment at a decent standard of living, but in order that this development should not be retarded an examination into our cost structure must be made, so that our manufacturing industries, if they are to continue, may become self-supporting. Statistics will show that the gross value of production per head of employees in South Africa is approximately half that of Canada, accountable in no small measure, no doubt, to the use of large numbers of relatively unskilled non-European employees, who, because their wages are comparativly low, are not employed in an efficient manner. It follows that the efficiency of the worker as productive unit is all-important.

Whilst the use of antiquated machinery, old-fashioned methods of production and our small local market are very big factors in raising our cost structure, I am definitely of the opinion that much can be done to develop our industries and to make them more economic by better training of our labour and using it more efficiently when it is trained. Our entire system of education and training from the time the person enters school must be designed to train a person to do a job in life, and not merely acquire a status. A trained person is an asset to the community, and is willing to fight for an improved standard of living, whereas a partially trained person tends to impoverish the country.

Broadly speaking, we can divide industry into two main categories for the purpose of employment in engineering—

(a) Those industries engaged in construction, maintenance and repairs, employing skilled journeymen, trained under an apprenticeship system together with apprentices.

(b) The secondary and/or manufacturing industries employing a sprinkling of journeymen, probably as supervisors, and large numbers of operators trained under a short learnership system.

In order that the support of the trades unions may be assured in the development of industry, it is absolutely essential to ensure that as far as it is possible unemployment is reduced to a minimum, and that the introduction of operators should not mean a threat to the skilled man, for it must not be the purpose to build industry on cheap wages, but rather by making the workers more efficient to reduce the cost. This now brings me to the question of training.

Training.—In my opinion both the artisan and the operators must be trained, the former to take his rightful place as a keyman, or a supervisor in the manufacturing section of the industry, and to staff our repair and maintenance establishments with skilled men, and the latter—the operator—to perform specific operations in manufacturing concerns. The training of the operator to be undertaken after he is placed in employment.

In order that this may be accomplished, I suggest that the Technical Colleges and Trades Schools in South Africa should be put under the control of a Technical Education Board on which the workers and employers will have representatives, and which will fall under the Union Department of Education; and this Board, in conjunction with the National Apprenticeship Board established under the new Act, will control all vocational training. Boys will be sent to the Technical Colleges at an earlier age, and by a system of aptitude tests will be guided to the different industries and trades.

Experience has shown in the past that far too many boys are indentured to trades for which they are not suited. Under the proposed scheme, when a lad is transferred to the workshops a record of his progress is kept, and he is moved through the various branches of the firm, or from firm to firm, to enable him to get a much better training and wider experience, and, in this connection, it may be advisable to indenture him to a trade in the industry, and not necessarily to a particular employer, in order to allow the apprentice to be transferred from firm to firm. Those boys not making the grade as artisans could be diverted to the manufacturing industries as operators. Every step should be taken by means of tours, bioscope illustrations, literature and lectures to improve the knowledge and efficiency of the worker. I believe it to be a fallacy that the development of manufacture means the shrinking of the opportunities of the journeyman, but on the contrary many more journeymen will be required, but they *must* be efficient.

In order, therefore, to provide for the maximum amount of employment greater efforts must be made to develop our secondary industries. No attempt should be made to manufacture a wide and varied range of articles merely because we happen to manufacture them to-day primarily because they are in short supply, and, further, no great reliance should be placed on protective duties which experience proved to be ineffectual as a permanent protective measure, and will probably, in the post-war world, not be tolerated by the nations as a whole. It will be in our own interest to arrange with the oversea concerns to come to some working arrangement. Because of our limited market greater attention will have to be paid to rationalisation of industry.

In my opinion, the Government should not undertake the running of industries, but leave this field to private enterprise. The duty of the Government is to see that the resources of the country are used to the best advantage for the people in the country, and not to leave our assets to be exploited for the benefit of a few. Therefore, State direction must be given to industry to see that the correct manufacture is undertaken, and that sufficient protection is given the firms undertaking that production, and not that a multitude of firms be permitted to undertake the manufacture of the same style of goods.

Whilst genius may conceive great ideas, it requires the energy of labour to translate those ideas into practical benefits. Trade unions are all too aware of the problems which will undoubtedly confront us in the post-war days, and consider that now is the time for authority, in whatever sphere it exists, whether it be academic or political, to locate and advise on our post-war possibilities and to start immediately to equip our labour potential to achieve its maximum possibility. Other countries, under the direct influence of war and its irresistible pressure, have been compelled to make the maximum use of productive capacity; in our country this has not been so. I submit that unless we have a scientific and planned approach to the future we in our country will be fighting our battles of readjustment, whilst other, more highly organised, countries will be laying the foundations of a peace economy.

Many of the non-Europeans now in the Armed Forces will be most useful in combating soil erosion, etc., farming will tend to become more mechanised, with the result that the non-European, with the knowledge he has gained in the mechanical transport doing his own running repairs, will prove of great value with farm machinery.

The development of our airways after the war can only be likened to the development of the motor industry in the last 20 years, and therefore we can confidently look forward to considerable employment in this field.

In my opinion, the Government should take steps to encourage the nationalisation of the transport and power industries, because these are essential parts in the industrial life of the country, and the cost to the consumer should be brought to a minimum.

In the opening of any new industrial area, cheap transport for the worker is essential, and the establishment of a network of electrical power lines will prove of great benefit to the country and to manufacture.

Private enterprise cannot stand the financial outlay for great schemes of this nature and, therefore, they must be established by public utility companies.

In conclusion, let me pay a tribute to the scientist whose sole ambition is the benefit of mankind, and who, when he can turn his inventive genius away from the creation of instruments of war to those of peace, and develop some of the marvellous inventions of this war, will give us hope for a better world.

This world can only be bettered, however, if we are all tolerant to one another and see each other's point of view.

No Government can succeed unless it has the co-operation of the people, and living in an age of the greatest tragedy we have the greatest opportunities.

The call to leadership has never been greater since the beginning of the world, and the whole of our future history now depends upon men and women who will put the cause before themselves and use their abilities and energies to create a brave new world for their posterity.

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(4) THE RETURNED SOLDIER

BY

H. WELSH,

Deputy-Director of Demobilisation.

I have no faith whatsoever in the general public to see that the soldier after the war is reinstated. During the last four and a half years I have watched the machine geared down, and immediately peace is declared an overwhelming majority of the people will swing away from war talk and the returned soldier. The real interest of this country is not the returned soldier but a selfish interest, and if we were to depend on the public the state of things in this country would be worse than after the last war.

The soldier has, however, been promised many things by you, and he can see to it that he upsets all the little smug ideas of those who would swing away. There would be a call on behalf of the returned soldier to develop a national consciousness to face the problem that would arise after the war. The greatest danger would lie in allowing the soldier to be left out in the cold whilst those who had not been in the war attempted to take advantage of the opportunities which would arise immediately after the war. Any attempt to treat the soldier of to-day in the manner of the past war could result only in chaos so far as South Africa is concerned.

The problem of employing the returned soldier after the war could only be solved in a large measure by a definite increase in the productive capacity of the Union in all the phases of employment, a task in which scientists could be of great assistance. In addition to South Africa's 200,000 soldiers, there are 70,000 people employed in war production to-day, and of these 40,000 are wartime operatives; all these people would have to be absorbed into peacetime employment. The plans for doing this must be brought to a practical issue before the soldiers return.

The Public Relations Section of the Demobilisation Directorate has been created to consider every idea designed to help in any way to solve the problems of the country when the soldier returns. All such ideas would be welcome; the effort is being made to harness the brains of every person in the country. This time, if anything goes wrong on the return of the soldiers, there will be no question of blaming the Government—it will be the general public which has let the men down. For the first time, the Government has handed over the investigation of every soldier's case to a public body of citizens. Ninety per cent., or even more, of the recommendations of this body will be agreed to by the Directorate of Demobilisation.

All men who were willing to work must be found suitable work: *that was the promise which had been given, and must be carried out;* employment must, however, be on the basis that the work is of economic value—there must be no palliatives. such as the Dole. As regards loans, it was fundamental to the scheme that a loan must be specifically a means to employment; applications for a few hundred pounds to tide a man over would not be granted.

The Demobilisation Directorate is now issuing a questionnaire to all serving men and women to see to what section of civil life they wished to return. Specialised committees would examine the employment possibilities of 800 possible vocations that these serving people could enter. Steps are also being taken by Universities, Technical Colleges and many other bodies to see that every man gets a job to which he is suited. No similar organisation to cope with 200,000 soldiers and 40,000 workers in straight-out war production factories had ever before been evoked, and the magnitude of the task can well be imagined.

The men on service have done a marvellous job, and the least we can do after that is to go all out to see that they get what they want on their return. If we cannot give them what they want, then the least we can do is to give them of our best.

(5) SOME ECONOMIC ASPECTS OF RECONSTRUCTION

BY

PROF. S. HERBERT FRANKEL

I have been asked to deal with the financial implications of reconstruction. Let me say at once that I am not going to burden this meeting with innumerable financial statistics and calculations. I shall as an economist—i.e. a social scientist—take this opportunity of addressing scientists in other fields on the fundamental issues involved. Financial aspects of any policy are but the expression in monetary terms of the cost of pursuing certain ends or objectives. The economic cost of attaining any one end or objective is but a measure of the alternative ends or objectives which have to be relinquished in order to attain the purpose we have chosen.

These considerations are of the utmost importance to scientists, and they lie at the root of all discussions in regard to reconstruction plans. Unfortunately, the fact that the possible objectives of social policy are unlimited, while the means at the disposal of the society for the attainment of its desires are scarce, is all too frequently overlooked.

For this a great deal of blame must be attached to the utterances of technical experts who are unacquainted with sociological and economic analysis. To an increasing extent they have, in recent years, turned their attention to the general problems of society, and are suggesting new objectives of social policy. This is a valuable departure. For too long many specialists have kept their discoveries to themselves for use in restricted fields. Now they are acting as citizens, not merely as specialists, and endeavour to make their contribution also to the formulation of social policy. They are taking up the task of guiding social opinion as to the objectives which society should pursue, and how it should utilise its resources for the realisation of new social ends.

Thus the technicians and specialists have entered into the political arena—into the arena of government. They make their voice heard as to what Government should do, and how it should use its powers of influencing the types of goods and services produced by the economy through fiscal and social policy or by Government edict.

As I have said, this new role of the citizen-scientist is in many respects a most valuable one It is indeed a part of that significant change in the general climate of social thought which distinguishes the objectives of the Allied Nations in this war from that of the war of 1914-18.

On a previous occasion[1] I drew attention to the contrast between the principles enunciated in what is known as the

Atlantic Charter and the famous Fourteen Points enunciated by President Wilson on the 18th January, 1918, as the basis of the peace with Germany. The characteristic feature of President Wilson's Fourteen Points was the insistence on the right to self-determination of nations *per se*, with the implication that the world would be made fit and safe to live in if it was a world fit and safe for every peace-loving nation. The characteristic feature of the Atlantic Charter is not political, it is economic. The political self-determination of nations is no longer the end—it is the means, and the final objective is the economic welfare and security of all men. The fifth point of the Atlantic Charter states that the Allies "desire to bring about the fullest collaboration between all nations in the economic field," and the object of that collaboration is defined as the "securing for all improved labour standards, economic advancement and social security." The sixth point re-emphasises this objective. It states: "After the final destruction of Nazi tyranny they hope to see established a peace which will afford to all nations the means of dwelling in safety within their own boundaries, and which will afford assurance that all the men in all the lands may live out their lives in freedom from fear and want."

The keynote of the Atlantic Charter is, therefore, the self-determination, not of the nations, but of the peoples of the world in order to achieve economic progress and security for the citizens of the world.

It is frequently stated that the Atlantic Charter is simply another scrap of paper containing high ideals but no real desire to see them put into practice. To argue thus is to miss the real significance of all such documents, which lies in the fact that they express the beliefs which dominate men's thoughts and aspirations. Utopias are important not because they are realised, which, of course, they never can be, but because they lead men in one direction rather than another. The better the Utopia the more likely are we to achieve the good rather than the bad in so far as it lies in our power to do so.

The new climate of thought, of which the Atlantic Charter is one expression, is also illustrated by a recent declaration in the report of an economic delegation appointed by the Council of the League of Nations[2], which stated that the objectives of economic policy should be to assure—

(1) That the fullest possible use is made of the resources of production, human and material, of the skill and enterprise of the individual, of available scientific discoveries and inventions so as to attain and maintain in all countries a stable economy and rising standards of living.

(2) That, in so far as possible, no man or woman able and willing to work should be unable to obtain employment

for periods of time longer than is needed to transfer from one occupation to another or, when necessary, to acquire a new skill.

(3) That in the use of these productive resources the provision of goods and service to meet the essential physiological needs of all classes of the population in food, clothing, house room and medical care, is a prime consideration.

(4) That society distribute, as far as possible, the risk to the individual resulting from interruption or reduction of earning power.

(5) That the liberty of each individual to choose his own occupation is respected, and is promoted by equal educational opportunities.

(6) That the liberty of each country to share in the markets of the world, and thus to obtain access to the raw materials and manufactured goods bought and sold on those markets is promoted by the progressive removal of obstructions to trade.

(7) That the benefits of modern methods of production are made available to all peoples both by the progressive removal of obstructions to trade and by courageous international measures of reconstruction and development.

The influence of modern scientific and technological advance is clearly visible in this new expression of economic objectives, particularly in regard to the stress laid on the physiological needs of all classes of the population in food, clothing, house room and medical care.

But here I must pause in order to examine certain pitfalls of which would-be social-scientists must be warned if their urge to rouse the awareness of society to hitherto unfulfilled social or individual needs is not to make confusion worse confounded. The danger lies in the fact that they will fail to see the forest of society, but concentrate only on the group of trees with whose growth and cultivation each of them is trained to be concerned. Economists or social scientists whose function, let me remind you, is to endeavour to unravel the laws of growth of the forest as a whole, frequently stand appalled in the face of the innumerable plans for reconstruction which spring up higgledy-piggledy like creepers and threaten to choke the normal growth of whole sections of the forest altogether.

Let me just remind you of a few of the demands put forward by scientists and planners in recent years. First of all there is a demand for a complete system of medical care, on a standard previously never reached, involving the building of hundreds of new hospitals, the training of doctors and nurses in large numbers, the development of specialised medical services of all types, the improvement of conditions of nursing,

the institution of large schemes for occupational therapy and, of course, the raising of taxation on the income of the citizens to pay for the upkeep of all these important services. Then there are those who put forward grandiose plans for better housing. With great zeal they have linked up with the town planners and the regional planners, and raise our enthusiasm with beautiful sketches of how whole towns and regions should be rebuilt. These, with a commendable spirit of co-operation, link up next with those who say that good houses must be inhabited by good citizens, and so their blue-prints of the modern City Beautiful include ample provision for communal centres, schools, village greens, playing fields, museums of art and culture, and naturally too for a new body of workers, newly-trained teachers, social workers, psychologists, etc.

All these conscientious endeavours are next supplemented by the plans of another group of scientists who urge that medical care, good housing, culture and education cannot still the demands of the human stomach. They wish to make the City Beautiful also a City Bountiful. They insist on the need for well-nourished bodies, and conduct a ceaseless crusade for higher and better nutritional standards. They argue for a new army of workers on the land, and in the laboratories, to produce the proteins, minerals and vitamins which will not only feed the hungry but nourish those properly who have never felt a pang of hunger at all.

The examination of problems of nutrition has aroused others to conduct a crusade for saving our soils. They shower upon us demands for workers (and, of course, incidentally, financial resources to pay them) to make good the ravages of soil erosion, to re-educate those who misuse the land, to engage on large projects for undoing the evils of past neglect, and to devise new techniques for preventing the ruin of what they point out is the basic gift of nature on which we all depend.

But I am not yet through with the list of demands which have sprung up around us. Thousands of experts are ceaselessly engaged in studying the effects of modern processes of production on the worker himself. They demand better factory conditions, shorter hours of work, the elimination of undue fatigue, the provision of recreation and rest, the improvement of the psychological conditions under which men and women work, and the prohibition of work for those who are too young or for those who require special attention to safeguard their health, e.g. child-bearing women or partially incapacitated workers.

Lastly, the workers themselves, subject to all the terrible risks from which they suffer in a society like the modern one in which the methods of production and the ends of production are subject to continual change, have rightly demanded that social arrangements should be made to protect them from the

industrial risks which threaten their employment, their health and their livelihood—risks over which they have no control. They demand social security, that is, social insurance against occupational risks, unemployment, invalidity, sickness and industrial diseases.

In truth, the social conscience of the modern world is sorely troubled, and out of its travail a new world is being borne. But amid all these demands which appeal rightly to our emotions, the voice of reason and responsibility is too frequently stilled. I fear that if we are not careful the vision of the future, which each group of experts would like to see realised, will simply remain a vision beautiful. Indeed, there is the danger that some of these beautiful visions will be used by those who threaten our political liberties as a means of propaganda and a facade behind which they can attain power for themselves—and nothing more.

For what the economist fails to find among all the advocates of these excellent proposals is a sense of responsibility. That sense of responsibility will only develop when there is a greater awareness of the fundamental problem of society, the problem of reconciling wishful thinking with reality, and one particular wish with another. In other words, it will only come from a greater awareness of the fundamental problems of government in economic and political affairs. The problem of government is to reconcile the different wills of the peoples so that they will demand the attainable and refrain from irresponsible clamour for that which cannot yet be attained. Democracy is a method of government which endeavours to reconcile conflicting policies—by counting heads and not by breaking them—and its counterpart in the economic sphere is the registration of the intensity of conflicting wants on the free market and the constant adjustment of the forces of supply and demand through the market mechanism.

That, in fact, all these various plans for reconstruction, no matter how good each may be in itself, involve decisions as to what shall be done first, what second and what not at all, and that they cannot all be done at once(3) does not in general appear to be realised by the modern expert who has turned social reformer.

For long I have wondered why so many modern scientists are attracted to support forms of authoritative government which do not bother about reconciling the wishes of the governed, but proceed to attempt by force to cut the Gordian knot and, in doing so, reduce the citizen from his place of responsibility and decision for public policy to one who has nothing to decide because everything from birth to death will be decided for him.

I believe that the explanation recently given by Professor Hayek in his challenging book, "The Road to Serfdom," is one

that deserves the serious attention of the Association which I to-day have the privilege of addressing. The explanation of this demand by so large a proportion of our experts is, he states—and I do not hesitate to quote his contention at length—" closely connected with an important fact which the critics of the planners should always keep in mind: that there is little question that almost every one of the technical ideals of our experts could be realised within a comparatively short time if to achieve them were made the sole aim of humanity. There is an infinite number of good things, which we all agree are highly desirable as well as possible, but of which we cannot hope to achieve more than a few within our lifetime, or which we can hope to achieve only very imperfectly. It is the frustration of his ambitions in his own field which makes the specialist revolt against the existing order. We all find it difficult to bear to see things left undone which everybody must admit are both desirable and possible. That these things cannot all be done at the same time, that any one of them can be achieved only at sacrifice of others, can be seen only by taking into account factors which fall outside any specialism, which can be appreciated only by a painful intellectual effort —the more painful as it forces us to see against a wider background the objects to which most of our labours are directed, and to balance them against others which lie outside our immediate interest and for which, for that reason, we care less.

" Every one of the many things which, considered in isolation, it would be possible to achieve in a planned society, creates enthusiasts for planning who feel confident that they will be able to instil into the directors of such a society their sense of the value of the particular objective; and the hopes of some of them would undoubtedly be fulfilled, since a planned society would certainly further some objectives more than is the case at present. It would be foolish to deny that the instances of planned or semi-planned societies which we know do furnish illustrations in point, good things which the people of these countries owe entirely to planning. The magnificent motor roads in Germany and Italy are an instance often quoted —even though they do not represent a kind of planning not equally possible in a liberal society. But it is equally foolish to quote such instances of technical excellence in particular fields as evidence of the general superiority of planning. It would be more correct to say that such extreme technical excellence out of line with general conditions is evidence of a misdirection of resources. Anyone who has driven along the famous German motor roads and found the amount of traffic on them less than on many a secondary road in England, can have little doubt that, so far as peace purposes are concerned, there was little justification for them. Whether it was not a case where the planners decided in favour of ' guns ' instead of 'butter '

is another matter([4]). But by our standards there is little ground for enthusiasm.

"The illusion of the specialist that in a planned society he would secure more attention to the objectives for which he cares most is a more general phenomenon than the term of specialist at first suggests. In our predilections and interests we are all in some measure specialists. And we all think that our personal order of values is not merely personal, but that in a free discussion among rational people we would convince the others that ours is the right one. The lover of the countryside who wants above all that its traditional appearance should be preserved and that the blots already made by industry on its fair face should be removed, no less than the health enthusiast who wants all the picturesque but insanitary old cottages cleared away, or the motorist who wishes the country cut up by big motor roads, the efficiency fanatic who desires the maximum of specialisation and mechanisation no less than the idealist who, for the development of personality, wants to preserve as many independent craftsmen as possible, all know that their aim can be fully achieved only by planning—and they all want planning for that reason. But, of course, the adoption of the social planning for which they clamour can only bring out the concealed conflict between their aims.

"The movement for planning owes its present strength largely to the fact that, while planning is in the main still an ambition, it unites almost all the single-minded idealists, all the men and women who have devoted their lives to a single task. The hopes they place in planning, however, are not the result of a comprehensive view of society, but rather of a very limited view, and often the result of a great exaggeration of the importance of the ends they place foremost. This is not to underrate the great pragmatic value of this type of men in a free society like ours, which makes them the subject of just admiration. But it would make the very men who are most anxious to plan society the most dangerous if they were allowed to do so—and the most intolerant of the planning of others. From the saintly and single-minded idealist to the fanatic is often but a step. Though it is the resentment of the frustrated specialist which gives the demand for planning its strongest impetus, there could hardly be a more unbearable —and more irrational—world than one in which the most eminent specialists in each field were allowed to proceed unchecked with the realisation of their ideals. Nor can 'co-ordination,' as some planners seem to imagine, become a new specialism. The economist is the last to claim that he has the knowledge which the co-ordinator would need. His plea is for a method which effects such co-ordination without the need for an omniscient dictator. But that means precisely the retention of some such impersonal and often unintelligible checks on individual efforts as those against which all specialists chafe."

And here let me mention that this dispute between the modern planners who want centralised authoritative control and their opponents is "*not* a dispute on whether we ought to choose intelligently between the various possible organisations of society; it is not a dispute on whether we ought to employ foresight and systematic thinking in planning our common affairs. It is a dispute about what is the best way of so doing. The question is whether for this purpose it is better that the holder of coercive power should confine himself in general to creating conditions under which the knowledge and initiative of individuals is given the best scope, so that *they* can plan most successfully; or whether a rational utilisation of our resources requires *central* direction and organisation of all our activities according to some consciously constructed "blueprint." The socialists of all parties have appropriated the term planning for planning of the latter type, and it is now generally accepted in this sense. But though this is meant to suggest that this is the only rational way of handling our affairs, it does not, of course, prove this It remains the point on which the planners and the liberals disagree."

Moreover, it is very important not to confuse opposition against this kind of planning with a dogmatic *laissez-faire* attitude. The liberal argument is in favour of making the best possible use of the forces of competition as a means of coordinating human efforts, not an argument for leaving things just as they were. Nor is it an argument against the exercise by the democratic state of its great and expanding positive economic functions in undertaking those tasks for which it alone is suited and which cannot be left to be undertaken by other forms of enterprise.

But we must beware also of making a fetish even of the democratic state and of democracy itself. It cannot be said of democracy as Lord Acton truly said of liberty that it "is not a means to a higher political end." Democracy is essentially a means, a utilitarian device for safeguarding internal peace and individual freedom. But it is by no means infallible or certain. It is not true that so long as an ultimate source of power is the will of the majority the power cannot be arbitrary. Democratic control *may* prevent power from becoming arbitrary, but it does not do so by its mere existence. That is the real danger which faces us.

If in response to the probing of the moral conscience of our time we establish means of government which involve conferring arbitrary powers on the few, or even on the many, we will become the slaves of arbitrary power. We will lose the supreme value—the value of free man himself—in comparison with which the realisation of any particular specialist, expert or group demand for this or that better commodity or service pales into insignificance.

In the words of Lord Acton, "all power corrupts, absolute power corrupts absolutely," and "liberty is not the means to a higher political end," or we may add to mere economic ends. "It is itself the highest political end."

It is not, moreover, merely an individual end. The development of society itself depends upon it. No society can conquer its environment unless it gives the fullest possible scope to the individual within the framework of the social law which it creates. The individual must be permitted to inaugurate those multitudinous organic adaptations to the social surround which we call progress and of which he alone is capable. True civilisation involves the creation of a synthesis between the individual and the community, domination of either by the other must inevitably spell stagnation and defeat for both. Just as a tree cannot live and prosper alone, so, too, the forest cannot grow without the individual powers of adaptation of the trees that constitute it.

In the words of a contemporary American author(5): "It is a fundamental postulate of democracy that the individual is of infinite worth—so towering in the scale of values that he has rights even against the State. Democracy, that is to say, is based upon a moral absolute—not the relative worth, not the financial worth, not the economic potential, but the spiritual worth of the individual human being." Walt Whitman, American to the core, phrased it with all the passionate intensity at his command: "In the centre of all, and object of all, stands the human being, toward whose heroic and spiritual evolution poems and everything directly or indirectly tend, Old World or New."

"The essence of the democratic process is the moral, intellectual, and social integer—the individual—living his life with a maximum of freedom and a minimum of external restraint, with the accent upon accommodation and consensus rather than plan or enforcement."

Thus the creation of income resolves itself, in the last resort, into nothing other than the creation of opportunities for the growth of human personality in its ceaseless struggle to adapt itself to its surroundings, to bring new experiences from it, and to partake of satisfactions from new events. And the key-note of modern production of income, as I have shown elsewhere(6), is that it depends not on the immediate environment in which any of us live, but on our co-operation with others at home and abroad. The development and enlargement of our experiences depends on the concomitant growth of the range of experiences and activity of others. It is based on our close contacts and contracts with them. In the modern world economy the income-creating process is not the result of the actions of any particular groups of individuals in any particular society or any particular nation. It is an intangible movement through space and time, without beginning or end, without any

precise boundaries or limit; a process which cannot be stopped or diverted at any one link without affecting directly or indirectly every other link in the endless chain.

All this can be summed up in the general statement that any action taken by society which inhibits the full development of the potential powers of any individual or sections of society lowers the income, that is the attainable range of experiences, of the society as a whole. Thus the problem of reconstruction consists neither in merely conjuring up visions of this or that goal, nor in the mechanical preparation of blue-prints, nor in the giving of orders by any single authority, but in the elimination of obstacles to the opportunity of individuals to utilise and expand their horizon of achievement, and thus to develop society's productivity to the full.

I believe that experts, technicians and scientists can render no greater service at the present time in the Union than to expose constantly and continuously the obstacles to the full use of our *human* resources. They must develop the social conscience of the Union not only in regard to the things they should wish to have done but in regard to the fundamental obstacles which prevent our doing them. Let them, for example, not merely demand more education but ask how many thousands of persons who are anxious to train themselves to be educators are prevented from obtaining that training. Let them ask not only that more products should be manufactured but also why thousands of potential workers are refused the right to learn the skill and obtain the opportunity to undertake jobs which modern production requires of them. Let them not merely demand new medical and allied services, but let them ask why so many would-be entrants into these occupations are prevented from supplying them. Let them not only demand new houses, but let them ask why so many prepared to learn how to build them are not allowed to do so. Let them demand not only the removal of the evils of soil erosion, but let them ask why it is that most of the workers on the land work only with their hands, not not with trained minds or with a stake in the land on which they live. Let them demand not only social security by insurance, but let them ask why means to achieve it are not more plentiful. Let them look upon the vast natural resources of the Union and ponder over the fact that they remain locked in the bosom of nature because we lack the skilled human resources to develop them. We lack that all-powerful human power because, not only do we refuse to utilise the capacity of the present population of the Union to the full, but we refuse obstinately to open our doors to those whose experiences, knowledge and personal contacts will help to develop them by greater co-operative specialised effort at home and wider markets abroad.

I have stated on a previous occasion, and I repeat, that the two greatest obstacles to the further development of the

productivity of the Union—the greatest obstacles, therefore, to reconstruction—consist in the fact that we deliberately limit our productive capacity by an outworn social and economic code which prevents our own population from becoming economically fully effective and that we at the same time refuse also to receive an addition to our population, and consequently to our capital and enterprise, from other countries.

The keynote of economic and social policy in the Union is at present fear. We have lost confidence in our ability to receive others into the structure of our civilisation. We are ridden by economic and political bogies. We are like the man in the fable who was so afraid that whenever he took a step forward he took two steps backward. Fear is a bad counsellor and a worse master. For it infects not only those who are slave to it, but others who have not yet fallen under its sway. At the present moment psychological conditions are being created in the Union which run counter to all the forces which have so far sustained us in conquering the particular problems of our environment and wringing income from it. We drew our strength originally from overseas, both in capital and in human skill. We are still fundamentally dependent for the development of this great continent on that link with the world economy. But our own internal affairs and civil strifes are fast bringing about a situation in which those with contributions of skill, enterprise and capital to make will not come here because our own lack of confidence in our society will frighten them away.

What inducement can there be for an individual to risk his capital or his livelihood in an environment which openly expresses its antagonism to his coming, and which is so confused in regard to the objectives of social and political policy that it flirts at every turn with movements which seek salvation in the methods of dictatorship and the suppression of individual liberty.

Let us not forget that all talk of reconstruction and of social security is illusory in a State which may be divided against itself, or threatens to be so divided, and which has not yet learnt the fundamental lesson of this generation that the whole cannot gain by measures which prevent the development of its constituent parts. Just as no nation stands to gain by inhibiting the development of any other nation, so no nation can gain a tittle of economic advantage by inhibiting the development or opportunities of any section of the inhabitants within its borders.

There are many who, in the spirit of defeatism which rules the times we live in, believe that liberty and security cannot be reconciled. They seek salvation not in the development but in the regimentation of man. They would secure the future not by strengthening man himself to conquer his ever-changing environment, but by weakening him and making him the slave

of bureaucrats, administrators and dictators. Once he is so enslaved what guarantee will he then have that his masters will succeed in protecting him against the dangers which he fears. Indeed, what protection against the ever-changing environment of man and nature can there be but the strength of character, of experience, of inventiveness and of adaptability of man himself. Destroy these and the mirage of security through the destruction of liberty will disappear, and the desert of lost opportunity will stand revealed in all its nakedness.

This is the mirage of our times. We in South Africa have not escaped its influence. We share in the world-wide retreat from reason and from liberty. But at any rate in most other countries that retreat has not gone so far as to lead men to believe, as we do here, that economic security can be attained by deliberately inhibiting economic productivity. Yet here we speak glibly of reconstruction based not on full employment but on the deliberate under-employment of our population, and refuse, in addition, to receive new population from abroad.

Let me remind you that in 1911 the real national income of the Union was about £48·4 per head of the occupied population. In 1942, 30 years later, it reached £84·8. The point about these figures which is constantly overlooked is that that growth was due entirely to the development of modern economic processes of production and to our closer contacts with the world economy resulting from international trade and the immigration of men and capital. So, too, the income attained 30 years ago was due to the great industrial revolution which began in the 80's and 90's, and before which time there existed a mere subsistence economy in most parts of South Africa. Our fundamental task therefore is still the old one of raising large sections of the population from unduly low, and often merely subsistence, standards to new efforts in keeping with the standards of productivity of economically advanced societies.

I see no reason why we should fear this task. But if we are to succeed, scientists must play their part and must be aware of the fundamental conditions on which the realisation of new possibilities of constructive endeavour and of constructive living depend. Those conditions are few but fundamental. I would sum them up as follows: We must ensure in our country political stability and the maintenance of constitutional and democratic government. We must guarantee the liberty of the individual and his freedom of enterprise, and we must grant these rights to those who do not yet possess them. We must expand our relations with the world economy, and in particular the international trade on which our present income standards have been built up. We must maintain economic confidence at home and attract the investment of capital from abroad. We must encourage immigration of enterprise and skill. We must propagate among the people a consciousness of the inescapable need for the abolition, by the process of democratic govern-

ment, of all restrictions on productivity and enterprise, whether these result from monopolistic privileges, from our present laws, from custom or from prejudices based on race, colour or creed. We must use the economic functions of government positively to create new income and not negatively to prevent the creation of income by others. We must co-operate to reduce, by the process of democratic government, unjustified inequalities of income, and establish a code of action in business and industry and a code of law which will give every member of the community a basic standard to protect him against the risk of unemployment, ill health, accident and disease.

But we must realise that security must be sought through strengthening the individual and strengthening his realisation that the power of the State to secure to him freedom from want and fear rests ultimately on the development of his own potential powers.

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(2) Report of the Delegation on Economic Depressions, Part I: "The Transition from War to Peace Economy." League of Nations, 1943.

(3) In part this is due to the impressive size of war production and the failure to observe the many goods and services which are *not* produced in order to make it possible.

(4) But as I am correcting this the news comes that maintenance work on the German motor roads has been suspended!

(5) Henry M. Wriston: "Why Not Try Freedom?" Harper's Magazine, August, 1943.

(6) *Ibid.*

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(6) A SCIENTIFIC APPROACH TO THE PROBLEM OF POST-WAR EMPLOYMENT AND THE NON-EUROPEAN

BY

MARGARET BALLINGER, M.P.

In this paper, under the term non-European, I shall deal almost entirely with the African aspect of the post-war employment question rather than with the non-European aspect generally. This is partly because the time at my disposal precludes the possibility of a detailed consideration of the special conditions of each of the groups which goes to make up our non-European population and I therefore naturally choose to do what I can to focus the problems as they effect the major group which has a more national significance than the other more localised groups. Nine-tenths of the Coloured population is in the Cape Province, four-fifths of the Asiatics in Natal. But the attitude of South Africa to colour being what it is, the problems of all non-European groups have certain fundamental similarities which lend a measure of justification to this method

of approach not seriously impaired by the very real difference which in practice keep all these groups separate.

The Scientific Approach.

The scientific approach to a social issue of the kind under consideration in this symposium seems to me to postulate two things; (a) a knowledge of the facts of the situation with which we have to deal and (b) a clear perception of the goal which we desire to attain.

So far as the first of these—to me, essentials of the scientific approach is concerned, the paucity of exact fact in respect of all sections of our population is one of the most conspicuous handicaps to any sort of scientific analysis. In every field of social and economic research, the student in this country is met early with all the difficulties and discouragements of the lack of statistical data which are commonly available in older countries where, as here, there is a growing desire to plan the future. But nowhere is the lack so conspicuous as in respect of our African population. Here we have not even the basic foundation of a regular and reliable count of the people. Our Native population have been counted three times only since Union. (1911, 1921 and 1936.)

The last count, as you will see, is now nearly ten years old. It is also the most accurate, but its value for comparative purposes, e.g., as a basis of computing population trends, is practically negligible, thanks to the absence of an adequate background against which to evaluate the information it might afford in that regard. Further, we have had one occupational census only in this section of our population, which means that here too, we have no yardstick by which to measure the changes in progress in African society, a knowledge of which is essential to responsible planning. Finally we have no registration of vital statistics (for the urban African population which means in effect, for the African population as a whole), to enable us to fill some of the gaps, and to give us their reflection of the social characteristics of the group (e.g., we know the existence of social diseases—typhus, plague, venereal disease, but we do not know their incidence).

In the circumstances, I would suggest that the first necessity of a truly scientific approach to this important subject should be the immediate institution of the registration of vital statistics for the African population—(a not impossible task as the registration of cattle statistics has long demonstrated, and as both the Statistical Council and the recent inter-departmental committee for Public Health and Native Affairs have alike maintained), and the equally immediate provision for a full census, both population and occupational, with the essential proviso that, in future, no excuse be admitted for omitting any part of the population from a regular five yearly count. At any time it is a false economy for the State to be without an adequate know-

ledge of the extent and character of the populations for which it provides government; but when government extends to positive responsibility in the social and economic fields, ignorance of these basic facts is not merely folly, it can be criminal folly.

But if we lack exact knowledge both of the African population and of the changes which are in progress within it as a group, we have a fair amount of general knowledge about this section of our population on which we can base fairly reliable estimates as to its social character. In some ways we have more information of this kind in respect of our African population than we have of any other section of the population, even the more privileged. This we owe partly to the awakening consciousness of the African in our midst, itself a product of a variety of circumstances of which the emergence of a new level of social conscience happily plays its part. This has led to a variety of sectional and specialised enquiries which have gone some way to making up the deficiencies of more basic sources of information; and these have provided a foundation for generalisation in which the margin of error is likely to be less than is usually the case with generalisations in the social field, thanks to the rigidity of the laws by which we govern our subject population; laws which have forced the development of this section of our population into certain broad channels and have prevented that degree of differentiation to which the progress of industrialisation has given rise within other racial groups. In other words, we know a good deal from sectional research, both public and private, about the conditions of life of the African in our society, while the controls and checks upon change which form the body of our statute law affecting Africans are so extensive that exact statistical data would probably not invalidate our main assumption in regard both to its distribution and to its general character.

Distribution and Population.

We know, for instance, that our African population falls into three groups, reserve, other rural, and urban. According to the 1936 census, the balance between them was as follows: In Reserves, 2,962,000; 2,196,000 on farms, mainly European owned and operated, 824,000 in urban residential areas and locations, rural suburbs and townships and native townships, and finally 613,000 on alluvial diggings, in industrial compounds, in construction gangs and in various other industrial occupations. The rural side of the population as represented by the first two groups, that is dwellers on farms and in reserves, constituted 78·2 per cent. of the whole Native population; but the two groups counted in urban areas or on industrial undertakings cannot be regarded as fully urbanised since a proportion at least were bound to have been rural people engaged in fulfilling longer or shorter periods of contract with industry, so that in effect, the proportion of the population which should be classed as rural

according to domicile was certainly more than the 78·2 per cent. noted above. In fact, the domiciliary basis shows some 82 per cent. of the 1936 African population still in rural areas. This large proportion of rural dwellers to urban in the African population group offers a marked contrast to that of all the other racial groups, the proportion of each of these to be found in rural areas according to the same census, being roughly one-third.

Occupation.

The Occupational Census suggests that a high percentage of the whole African population is gainfully employed. It shows 65 per cent. of Native males and 56·9 per cent. of Native females thus employed, an all-over percentage of 60·9 as against a total of 53·2 per cent. for all races combined, the total percentage for Europeans being 37·3, for Asiatics 29·3 and for Coloured 35 9. The comparative figures from Canada, Australia, Sweden. Germany and Great Britain quoted by the Industrial and Agricultural Requirements Commission suggest that the percentage of Native gainful employment is not only high for South Africa, but that it is high by the standards of these countries.

This occupation is, however, not by any means all rural and agricultural, as the domiciliary distribution of the population would seem to suggest. It is true that manufacturing industry would appear to absorb a very small proportion of our African population, both absolutely and proportionately, the actual figures for 1936 being 213,800 Natives and 140,204 Europeans, with an all over ratio of 2·1 non-Europeans to 1 European (the percentage increase of European employment in the preceding 20 years being 255 as against a percentage increase for non-Europeans of 212). But the essentially industrial occupation of mining accounts for a very considerable amount in the field of Native employment. In 1936 the number of Natives employed in this field was 393,000 as against 46,000 Europeans, giving an all over ratio of 8·5 non-Europeans to one European, approximately the same ratio obtaining in farming (8·3 non-Europeans to 1 European). This employment of Natives in mining, however, is not a reflection of the process of urbanisation.

Urbanisation and Migrant Labour.

We know from experience that the process of urbanisation which has been the characteristic movement of the European population, and indeed of all our other population groups, in this last generation is also going on among the Africans, but we are in no position to gauge its rate with any accuracy. The figures available from the 1921 and 1936 censuses suggest that the process is in fact much more rapid among the Africans than among the other groups of the population, but the biennial check census of Africans in urban areas to be held under the Native Laws Amendment Bill of 1936, has only been taken once, i.e. in 1938 The process is, however, undoubtedly slower than it

would be if African movement were as free as that of other sections of the population. As it is, it is subject to a variety of controls specifically designed to curb the process of urbanisation—that is of permanent urbanisation or a complete break with the rural areas and full dependence on industrial labour markets for a livelihood.

Migrant Labour.

On the other hand, partial urbanisation involving periodic dependence on wage earning in industrial (as distinct from agricultural) employment is the outstanding characteristic of the economic condition of the African group in our population—a characteristic which distinguishes it from all other racial groups in the country. From the Native reserves in particular, Africans stream in increasing numbers to the towns for varying periods of wage earning service in every field of employment, including, as the figures quoted above show, a considerable proportion employed in the mining industry. More detailed information supplied by the recent Mine Natives' Wages Commission (U.G. 21 of 1944) reveals the fact that among mine employees at least, these periods of urban employment are lengthening out while the alternate periods at home in the reserves are steadily narrowing. In 1930 and 1931, when the Native Economic Commission made its investigations, the average length of service of a Native mine worker was 10.88 months on the mines (based on a contract of 275 shifts), and the average period at home in the reserve was 8·1 months. In 1942 the period of service on the mines had risen to 13·6 months (based on a new contract of 352 shifts) with an average alternate stay in rural area of 7·6 months; while a growing percentage of labourers stay away for a much shorter period of service than the average ("statistics show that 81·3 per cent. of the Natives arriving at the W.N.L.A. Compound have been on the mines before; of these 7·76 per cent. have been away for one month, 6·17 per cent. for two months, 6·55 per cent. for three months. Thus 16·8 per cent. (or 20·66 per cent. of those who have been on the mines before) returned to work after what may be regarded as no more than a holiday visit").—Paragraph 209 of the above report.

This movement between town and country, which has tended to become the outstanding feature of the life of the reserve Native is not confined to that section of the Native population. It is also characteristic of a great part of the population domiciled on European farms. Here, however, the extent of the movement is much more difficult to gauge even approximately; but it is an accepted implication of the labour tenancy system which, although declining in popularity, still remains the characteristic type of labour organisation over a considerable proportion of the farming field, that the farm labourer will go to the town for a part of the year to earn the money with which his employment on the farm does not provide him.

ECONOMIC CONSEQUENCES OF MIGRANT LABOUR SYSTEM.

The system of migrant labour inevitably has its effects on the economic and social character of the people. A system which admits of alternatives between industrial and agricultural employment presupposes an extensive rather than an intensive use of available labour resources. It is a system which presupposed the unimportance of acquired skill; and inevitably it implies a corresponding degree of inefficiency. That inefficiency reflected in low productivity per head of the population is what it achieves is amply reflected in the level of our national income which has been the source of considerable heartburning since we began to talk of social security and to face the financial implications of achieving it (2s. per head per day for the whole population; some 7s. per head for the European population only).

ECONOMIC EFFECTS UPON THE NATIVE POPULATION.

For the Native population itself it is impossible to assess with any degree of accuracy the specific economic effect of the system; but there is some evidence to show that Native earnings have not reflected either such progress in industrial efficiency as has taken place over the last half century (and both in mining and in manufacturing there has been a marked improvement in productivity per head of the population), or the basic cost of the change in their standard of living which essential accommodation to western conditions and standards has involved e.g. in respect of food, clothing, housing and transport. A succession of agricultural censuses (complete censuses in 1920-21, 1925-26, 1929-31, 1936-37 with partial censuses in intervening years), tend to show that there has been a marked decline in the amount of cattle owned by Natives on European farms, but as there is no wage regulating machinery applicable to agriculture which would supply us with a periodic review of the conditions of farm employment, and as there is infinite variation in those conditions, we can only draw conclusions from the scattered facts that we have as to the extent to which this has been balanced by an increase in cash wages. These at least suggest that no adequate adjustment of cash wage to cover the loss of the privilege of cattle owning and grazing has taken place such as would have tended to maintain the stability of the farm labour population in periods of rapidly industrial expansion with its demands for an attraction to labour. Where specific information is available from localised surveys, it tends rather to suggest that the real wages of farm labour have tended to fall rather than to rise over this last generation. (*c.p.* Farm Labour Commission Report and the Study of Farm Labour in the Orange Free State, published by the S.A. Institute of Race Relations.)

MINING AND RESERVES.

Our evidence is more complete in respect of mining. Here the outstanding characteristic has been the sincerely perceptible

movement upwards of the earnings of the Native labourer, and the conspicuous failure of the labourer to share either in the progressive efficiency or the fortuitous advantages which the industry as a whole has enjoyed in recent years.

This no doubt reflects the failure of the migrant labourer's other resources to increase, and with their increase, to improve his bargaining powers in the labour market. In this connection the following comment of the Mine Wage Commission on the success with which the industry has both maintained its labour supply and its traditional wage rate is of special interest. It writes:—

> "Whereas formerly the Native in the Reserves, either on account of higher productivity of his land or because of his simpler tastes, was reluctant to leave his home, to-day he is forced by economic pressure to seek employment which will enable him to support his wife and family, and this pressure is so great that the gold mining industry is able, in spite of the competition due to increased demands of secondary industry, to recruit Native labour for underground work at a cash wage of 2s. per shift."

The Commission's own analysis of the productivity of Native reserve lands—the best of them, the Transkei, the pressure of numbers on the land and the deterioration of the soil which has taken place in the last two or three decades is probably sufficient commentary on this statement. (It shows that in the Transkei, of 260,000 families, 20,000 are without allotments, 44 per cent. of the people have no cattle and the average production of grain is 1·6 bags per *caput* per annum against a basic need of 2·75 bags. In the Ciskei, out of 47,000 families, 12,814 have no arable allotment and the production of grain per family is 8·1 bags per annum against a basic need of13·75 bags. The last annual report of the Department of Native Affairs sheds further light on the poverty of these areas.)

Thus it would appear that, for the mine Native as for the farm Native, there has been no marked change in his standard of living over the last generation. In both cases earnings are low and have remained low, and standards of living have necessarily remained low also.

Manufacturing Industry.

Where a relatively stable population has established itself in the towns in recent years, there have been belated signs of an upward tendency in wages and earnings. Since 1937, the Wage Board has supported a move to correlate earnings and a basic cost of living which has led to a considerable improvement over a large part of the labouring field. But the movement was very slow in starting; and the range of its effect on the general social and economic level of the Native population must be and is limited by the operation of colour bar and the civilised labour

policies which aim at reserving employment in the field of industry primarily for Europeans.

SOCIAL EFFECT OF MIGRANT LABOUR SYSTEM.

The social reflection of the economic position of our Native population is perhaps not surprisingly mainly a study in poverty and instability—poor health, poor housing, poor conditions, poor education, poor agriculture and increasingly poor discipline as family ties loosen under pressure of the migratory system.

NATIVE POLICY A CONSCIOUS CHOICE.

But these are the product of a deliberately chosen policy; and I believe, the foreseeable results of that policy, a policy of segregation—of Land Acts and Urban Areas Acts, of Colour Bar Acts and Civilised Labour Policies, and all the rest of the legislative record designed to keep the Native in his place, and defended as essential for the "production" of white civilisation.

The character of a state is not, never has been, and never will be simply the product of a set of uncontrollable economic forces; if it had been, South Africa would to-day be presenting a very different face from that which it is in fact presenting. The character of the state is, in varying degrees, the result of the choice of its citizens. That is why I have postulated as my second essential of a scientific approach to the problem of employment of the African in the post-war period, a clear definition of the objective to be aimed at, a positive decision as to whether we accept the proposition that the Native population must be integrated into the life of the country as a whole or whether it is to be regarded as a separate factor, to be used, manipulated and adjusted always as subsidiary in purpose and value, which is the essence of present day policy as expressed in the laws of the country.

URGENT NEED FOR RECONSIDERATION.

As a matter of fact a number of circumstances make this decision not only an essential condition of a scientific approach to a problem of employment which has only been focussed and pointed by the war, but an immediate issue both of Native policy and of general economic policy for South Africa.

(a) *Claims of Manufacturing Industry.*

The cry of shortage of Native Labour is not new in South Africa. It dates back at least to the beginnings of industrialisation at the end of last century. It has become steadily more insistent since then, particularly from the farming section of the community which early developed a sense of conflict of interests between itself and the mining industry which it learnt to regard primarily as a privileged competitor for the available supplies. As for the mining industry itself, only once in its history has the supply of Native labour equalled the demand—that was in the worst days of the last depression. Since then,

with the widened prosperity of the industry and the contingent growth of manufacturing industry, the demand has consistently outrun the supply in spite of the progressive extension northward of the field of recruitment; and now recent pronouncements by representatives of the industry suggest another conflict in our economic life arising out of the claims of manufacturing industry to an increasing share of the available resources. We have been told in recent months that the Native labour situation is critical and with it, the stability of our whole economy. We have been warned that the foundation of the whole of our economic life is the gold mining industry and that anything which limits it or curtails its possible expansion must be disastrous to the nation as a whole.

(b) *Plans for Reserves.*

This warning has been uttered not only against the new competitors for the available supplies of Native labour, e.g., secondary industry; it has also been uttered, though in different circumstances and from a different quarter, against possible and probable changes in the character and conditions of the labourer himself. Presenting the case of the mining industry before the Mine Native Wage Commission, Mr. W. Gemmill claimed that "the basis of the employment of Native labour by the mines is in complete accord with the balanced South African Native policy laid down practically unanimously by Parliament after thorough investigation and discussion in 1936-37 and embodied in legislation, in particular in the Native Trust and Land Act, 1936 and the 1937 Amendment to the Urban Areas Act and reaffirmed by the Minister of Native Affairs in the House of Assembly on 26th February, 1943. In brief that policy is the enlargement and planned development of the Native reserves and the concurrent restriction on the number of Natives permitted in towns coupled with the proper housing of those so permitted. It aims at the preservation of the economic and social structure of the Native people in Native areas where that structure can be sheltered and developed. The policy is a coherent whole, and is the antithesis of the policy of assimilation and the encouragement of a black proletariat in the towns, divorced from its tribal heritage. The ability of the mines to maintain their Native labour force by means of tribal Natives from the reserves at rates of pay which are adequate for this migratory class of Native but inadequate in practice for the detribalised urban Native is a fundamental factor in the economy of the gold mining industry." Mr. Gemmill elaborated by adding that: "This subsidisation of the tribal Native by way of free land is a basic factor in the economy of the Union." Against the pressure for improved wages he urged that where the argument in favour of such improvement was based on the inadequacy of the landed basis of the mine labourer to provide him with a livelihood even with his periods of contract on the mines, it was the obligation of the Government to provide

adequate holdings for this class of Native. " If the employment of the so-called landless class of Natives necessitates the payment of an increased wage, then that class becomes unsuitable for gold mining employment, just as the urbanised Native cannot be employed on the mines because of the wage necessary to meet his requirements."

FARMING AND MINING ALLIANCE AGAINST URBANISATION.

In brief, the mining industry—if Mr. Gemmill speaks for it—shares with the Native Affairs Commission the conception of the Native reserves as a reservoir of cheap labour for South African industry; as apparently did the Mine Native Wages Commission if we may judge from its recommendations. This is an issue of immediate importance since the application of the 1936 Land Act is now in progress and the principles upon which it is to take place are at stake and must be decided. Here from an influential quarter comes what is implicitly the demand that the decision shall be in favour of principles which shall maintain the flow of cheap Native labour.

This is a demand which, whenever it is formulated, is likely to have the support of the bulk of the farming industry, the expansion of which has, like that of the mining industry, been based on cheap Native labour. Indeed, there are evidences that, at this stage of our history, these two industries may form an alliance against the new competitor in the field, in spite of past differences, and although the field of competition between the two has widened e.g. recent analysis of the directional flow of labour from the protectorates shows a heavy swing against farming in favour of mining—*vide* Farm Labour Comission, page 53, which reads:

> " The passes issued (to Basutoland Natives) to proceed (to the Union) for agricultural employment shrank from 15,237 in 1933 to 3,782 in 1937, while the total number of passes issued for labour purposes was virtually the same in each of the two years mentioned." Correspondingly the figures for mining rose from 25,803 in 1933 to 33,130 in 1937.

IMPLICATIONS OF COMPETITION OF MANUFACTURING INDUSTRY IN NATIVE LABOUR MARKET.

But this combination of our older economic interests against the new is something more than a mere repetition of the antagonism of farming to mining which characterised the inception of industry in this country, for the successful emergence of manufacturing industry into the field of competition for the available supplies of Native labour would involve something more than simply a sharing out of these resources on a more even basis than now exists. It would mean a change in the use of all available supplies of such labour with a corresponding change

in the character and the distribution of the Native population. For manufacturing industry, the untrained, unskilled, unstable labour which has formed the traditional basis of mining and agriculture alike in this country, is entirely unsatisfactory and uneconomic. Manufacturing industry must demand and must obtain the advantages of acquired skill in its labour force if it is to have any hope of establishing itself in a competitive world (and here let me sound a warning about the assumption that Native labour, because of its recently tribal background, is particularly suited to the mass production methods of modern successful industry on the ground that the passive intelligence is better than more active intelligence for repetitive tasks. Any understanding and satisfactory handling of modern industrial machines requires a degree of trained intelligence not so essential under earlier types of industrial organisation, while those best fitted to judge the demands upon the worker of mass production methods, or the repetitive task sustained at high speed, declare that these place emphasis on initiative and skill of an exceptionally high order).

This means then, that for progressive manufacturing industry, the migrant labourer is totally unsatisfactory, that on the contrary, a stabilised labour force with developed skills is essential.

Need for Developed Demand.

But the capacity of manufacturing industry to develop to the point at which it could become an important factor in our economic life, to the point at which it could on the mass production bases on which alone it could hope to establish itself in a highly competitive world of industry, presupposes a mass basis of demand for its goods must exist. In other words, the producer must also be a consumer; which in effect means that developing industry must be opposed to policies which aim at checking rather than encouraging a rise in the standard of living of the labourer even where this would have the effect of increasing the cost of his labour. Specifically this would inevitably mean industry would be bound sooner or later to oppose both the exploitation of the reserves as reservoirs of labour for mining or for any other enterprise, and the laws which now both prevent the farm labourer from coming to town or from becoming an independent agriculturist in the rural areas, both the reflection of policies designed to restrain his bargaining power in the labour market. On the contrary, in its own interest, it will be compelled to extend the principle of stabilisation of the urban population to the reserves and to the farming and mining labour forces as the essential condition of that rising standard of living on which its own expansion must depend.

But this will involve almost revolutionary changes in the organisation of both these industries. It will also mean ultimately the scrapping of the Land Acts. It is true, the attempts

of mining (both gold and coal) to extend the period of contract of the labourer suggests that that industry is not basically opposed to a stabilised labour force, while farming has undoubtedly suffered from too high a localisation of the Native rural population in town and country (including the reserves) must mean a sharp reduction in the supply of cheap labour which existing conditions have been primarily concerned to maintain.

This is an issue which those industries and the country as a whole will have to face sometime; and all the evidences are that this is the time at which it should be faced since the issues have already been raised, and raised in an acute form For the mining industry, it means the issue of the development of low grade ore and the longest possible existence of the industry against the development of high grade ore and a possibly shorter life. For farming, it means the alternatives of present extensive methods of production with low standards of mechanisation and output per head, and dependence on an uncertain export market, or progressive mechanisation based on scarcer and dearer labour providing a greater home market for local production.

Counting the Cost.

There will be strongly conservative forces against these changes; but if the community is to continue the exploitive policy of the past, maintaining the gap that policy has fixed between European and African, its decision to do so should be again a positive conscious decision taken with full awareness of the costs involved. To the extent to which it is conscious, and is a decision in favour of the old way of life, it must have counted the costs involved. Of these, the following are perhaps the most important. First of all, while white South Africa can justly say that the exploitive policy has paid it pretty well in the past, it must remember that, even at the height of a period of phenomenal industrial expansion such as that through which we passed in the years immediately preceding the war, and in spite of all the artificial protection provided by a partial and paternal government for Europeans in need of employment, the Government itself had, in 1939, to find employment either at the expense of established members of other racial groups or on specially subsidised employment for over 40,000 men, that is, industry on the level of its production based on existing demand could not meet the need for employment even of the privileged minority of our population which the older economic interests of the country had been unable to satisfy. In the meantime, there is reason to believe that the process of exploitation is having effects of the sources of Native labour supply reflected in physical deterioration which, if the supplies are to be maintained and to meet expanding demand, will necessitate subsidisation from general revenue in the form of social services to bridge the gap between prevailing standards of earnings and

basic living costs. (N.B. the Social and Economic Planning Council feels that the physical deterioration of the people has progressed so far that this cannot be avoided in any case Unfortunately, the Government pays little attention to the social and Economic Planning Council—or little that we can see.)

And the deterioration extends not only to humans but also to the land. One of the most alarming reflections of our unstable rural population without adequate resources of time, capital and education is to be found in the condition of Native reserves to-day, where the ravages of soil denudation and erosion are assuming catastrophic proportions.

The Human Factor.

Yet South Africa being what it is, may be prepared to pay all these costs for a policy which maintains the principle of the inferiority of non-European to European and reduces the possible points of development of anything other than the master and servant relationship. But there is one further cost that must be faced in doing this; and that is inherent in the fact that the non-European like the European is a human being.

In the past, the African has accepted the policies that have cribbed, cabined and confined him with a good humoured resignation that is without parallel in social history But in the last decade or two he has been moving; widening experience of western civilisation has been opening his mind and stirring his ambition. And then came the war. Well, these war years have established new expectations for him as for the hitherto less fortunate members of other racial groups—not only in the army but in industry where typical wartime labour scarcities have given him new opportunities and provided him with new standards of living. None of these have been pegged for him any more than they have been for any other section of the community; less for him than for some others; but if he must relinquish them in favour of the claims of others, he will not do it with a good grace nor will he be content to do so indefinitely. And on the basis of a discontented helotry no social security for any group in the community can be built.

These are some of the matters which we shall have to face in South Africa, if we are to achieve anything that can be called a scientific approach to the problem of post-war employment whether in respect of the non-European or of any other group. They are matters of economic and social fact—and as such, are susceptible of scientific analysis; but in the last resort the decision upon them will be political, the responsibility of you and me not as scientists but as members of that minority group upon which monopoly of political power rests, quite unjustifiably, the claim of this country to be a democracy.

(7) SUMMARY OF CONCLUSIONS

BY

F. A. W. LUCAS, K.C.

There has been a great measure of agreement, upon the many points, among the speakers at this symposium. All agreed that there would be a post-war unemployment problem and that many troubles would have to be faced. There has also been complete agreement on some post-war aims, as for example, that there should be no unemployment after the war and that food in plenty should be provided for everyone.

There was also a considerable amount of agreement about the principles of the Atlantic Charter, although that charter might easily be interpreted in ways that suited political interests, in which event there was a grave danger that it would lead to nothing.

It was easy to draw a picture of all that is needed, but there was great divergence of views as to how all the desired things should be obtained. As, however, we are all serious about the very real problem of post-war employment, it is our duty to prepare at once to make sure that when there is an abundance of hands willing to work, there should be enough for all to do. This view was common to many of the contributions; but the fact that there are many willing and competent workers who could employ themselves or alone find employment, but are prevented from doing so by sundry obstructions, has not received the mention it deserves.

Some people had the idea that there was a limited amount of work, and that it could be so rearranged that everyone could share in it. But there was the other argument—that on the present national income there was not sufficient work to provide full employment for all, so that the post-war problem could not be solved on the present national income. Several speakers had suggested that labour, European and Native, must be trained to become highly efficient employees. But with every employee highly skilled, where were the jobs to come from? When this question can be answered, the subject of post-war employment can be dealt with on a scientific basis.

The Minister of Agriculture said this morning that the farming industry had met the country's food needs during the war; in a superficial sense that was true, but the bed-rock fact is that the great majority of the people never had enough to eat. The country's first essential was food, and that is politics in its proper sense. The agricultural industry must be the first to be developed. Even now the farming industry was not entirely meeting the people's needs. The basis of the whole

system must be the production of food, and then the production of other essential requirements, such as clothing and housing

Have the speakers in the symposium suggested anything that was new, or that differed in anything more than degree from the measures that were tried before the war?

It is generally acknowledged that there will be serious problems of post-war unemployment. It is known that before the war there was widespread fear of want and a widespread sense of insecurity, and that public bodies adopted many measures to feed the hungry and to counter unemployment. But they failed.

This went on for some time during the war, until recruiting had absorbed the unemployables and war work of one kind or another had provided employment for the remainder. But when the war is over the whole problem will revert to what it was, unless steps are taken now to meet the trouble that existed before the war and, on all reasonable grounds the conditions must be expected to be worse when the war is over. Why should the measures which failed before, succeed now? Relief works and better training are not solutions. It has been suggested that industries should be developed in this country economically, but it has not been suggested how this is to be done.

The post-war employment problem is not only that of the returned soldier, but affects the men who are holding the soldiers' jobs while they are away and who will be ousted from work when peace comes.

One of the features that has been most encouraging in this symposium is the faith shown by the speakers in the possibility of our having a better world which would solve the post-war employment problem. But faith must be accompanied by works.

The fact that we all want something better, and are prepared to talk about it, holds out hope that we shall in time begin to ask what must be done to get it. The measures adopted before the war did not give it to us. They will not do so now But this symposium may well open the way to measures that will be effective. We can take courage from the outspoken recognition that something is needed.

I would suggest a method of approach to our problem, which I believe I can claim as scientific and as linking up the aims of all the speakers and making possible the attainment of those aims.

If there is to be work for all, food for all, we must begin our investigation from the ultimate sources of both work and food—from our natural resources in man-power and land.

In a scientific approach to our problem should we not get down to the source of all we need? This symposium has been devoted to the most pressing form of our country's problem, but unemployment seems to me to be just a symbol of the evils from which we suffer. Unemployment leads to poverty which not only brings ill-health and inefficiency with it, but deprives us of real freedom and makes Nazism and dictatorship possible. We want to see that there is employment with freedom and security and a sufficiency for all, white and black.

I am sure that can be attained, but only if we scientifically ascertain the cause of unemployment and want, and then fearlessly attack and destroy it. I believe that cause lies in the monopoly control of our natural resources. Perhaps I may be forgiven for throwing out that issue as one worthy of investigation in a scientific approach to the problems of post-war employment.

INDEX TO CONTRIBUTORS.

SUBJECT INDEX.

Page

...but 97 didn't die

Out of the bleak story of war one shining chapter emerged: of every 100 wounded men to reach evacuation hospitals 97 recovered.

A vital part of this modern miracle of surgery and medicine was the organisation of the Red Cross. It started in the most advanced posts and stayed with the casualty till he was fit again. Like a friendly doorway that always says "welcome," its help greeted both the men in khaki and the men in white. In the days ahead such service is as essential as it was in the grimmer days of battle. Disabled and partially disabled men require not only a mapped future but the guidance of an agent acceptable to them. No matter what yardstick you apply, this too is a cause in which you must join, and do, when you donate to Red Cross.

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